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COMPETITION AMONG GRAINS

By
N. JASNY



**FOOD RESEARCH INSTITUTE
STANFORD UNIVERSITY, CALIFORNIA**

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To Phil

DIRECTOR'S PREFACE

Competition pervades economic life. It is fashionable today to stress the fact that competition is not pure and perfect, as writers on economic theory have often assumed for purposes of analysis, and to concentrate attention on imperfect or monopolistic competition. In historic time there have been changes in the degree to which competition has fallen short of perfection, and disputes rage over the trends. Most of this discussion, however, has dealt with competition among business concerns producing or marketing equivalent or similar commodities. Too little has been devoted to another important type: *inter-commodity competition*. This is probably now more vigorous than ever before. If it were given due weight, some current convictions regarding the drift toward monopolistic competition might undergo considerable modification.

This book deals with such inter-commodity competition, chiefly among the five grains which include all those of major importance except rice. It is concerned with their competition for various uses and for factors of production, under a great variety of conditions and circumstances. It seeks to disclose not only the fundamental factors involved in this competition among the grains, and their relative importance, but also the widely varying results as brought about by the combined effect of those factors in the different regions of the temperate zones of the Occidental world.

The work has evolved from a dream of the author. Naum Jasny's valuable experience in Russia, Germany, and the United States, and his familiarity with literature relevant to the present topic in all three languages, put him in an exceptionally favorable position to deal with its broad range in subject matter and geographical area. The Food Research Institute welcomed the opportunity to help translate the dream into achievement. While living in Germany, Dr. Jasny was for some years correspondent of the Institute covering Rus-

sian and German aspects of the world grain situation. For us he wrote "Wheat Problems and Policies in Germany," published in *Wheat Studies*, October 1935. The present book was written mainly while he held a temporary appointment as a staff member during most of 1938.

Most obviously the book will be of interest to agronomists, especially cerealists, for the attempted integration of findings in their field in the broad setting in which these are presented. Since few studies throw so much light upon the problem of geographical distribution of the world's important grain crops, it is clearly pertinent also to students of geography, particularly in its economic and agricultural aspects. It deserves to be read not only by agricultural economists and by students of marketing, but by economic theorists who do not shrink from taking realities adequately into account. Based on a vast and scattered literature, with the wide knowledge of the author supplemented and checked by others with general or specific knowledge on various phases, it has large significance not only for specialists but for "generalists."

The magnitude of the task largely accounts for the length of the book, in spite of persistent efforts to keep its scope within reasonable limits and painstaking pruning of the manuscript at successive stages. In part also the length is due to a desire to make the contents accessible to more than the specialists in the several aspects dealt with. Most of Parts I and IV, for example, will be found intelligible and interesting by those who may not care to follow the detail presented in Parts II and III and the Appendix.

Inevitably such a ground-breaking work will contain errors as well as gaps. Both the author and the Institute will welcome corrections, criticisms, and suggestions toward improvement, as well as additional literature on points covered herein.

JOSEPH S. DAVIS

September 30, 1939

ACKNOWLEDGMENTS

When this study was begun early in 1937, it was obvious that to accomplish it all by myself would be a very difficult, if not impossible, task. I was therefore very happy when I secured the co-operation of the Food Research Institute, with which I have been in contact for more than a decade. Aside from technical help and publication, the arrangement insured the consultation and active help of the members of the Institute staff, whose manifold backgrounds and interests contributed desired safeguards against gaps in knowledge and one-sidedness of judgment on my part.

The study in fact became far more an institutional work than any other that I have written. Additional, especially the very important qualifying, information; criticism of the content and form; suggestions for inclusions, omissions, reworking—all this was generously offered by the various staff members, to whom my sincerest gratitude is extended.

M. K. Bennett, Karl Brandt, and J. S. Davis heartily cooperated in all phases of the work, and Helen C. Farnsworth in the stages preceding revision, and for this reason their specific contributions cannot be pointed out. Dr. Bennett and Dr. Davis in addition lent a great deal of assistance in preparing the manuscript for the printer, carefully going over it more than twice and giving attention to every detail. Holbrook Working was a helpful consultant where price analysis was involved. V. P. Timoshenko read most of the final draft and made valuable suggestions.

Jean Hoover Ballou, my principal statistical and secretarial assistant, possesses a sense of responsibility rarely found but the more appreciated. The original charts are almost wholly the work of P. Stanley King, in plan, final make-up, and all; my own part in the preparation of some was even limited to supplying the basic material. Others, especially Elizabeth Brand Taylor, contributed in both different and similar ways—different with regard to the type of help sup-

plied and similar with regard to their unfailing willingness and friendliness.

The co-operation of the staff members is associated with my individual responsibility for the whole book. Individual responsibility is a potent means of stimulating productive effort; the study nevertheless would be materially inferior if I had been thrown upon my own resources.

To many other persons in the United States and abroad, I am greatly indebted for information, criticism, and suggestions. B. B. Bayles, Agronomist in the Bureau of Plant Industry, U.S. Department of Agriculture; J. S. Cole, Senior Agronomist, Division of Dry Land Agriculture in the same bureau; and L. E. Call, Director of the Agricultural Experiment Station of Kansas, who read Part II and made valuable suggestions. Major assistance affecting subordinate sections is acknowledged in the body of the study.

In 1937 I was able to obtain for another study a grant-in-aid from the Social Science Research Council which made possible a personal inspection of important agricultural regions of the United States. The principal outlines of the present study were at that time already developed, and the trip proved of great value for it.

N. J.

September 1, 1939

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CHAPTER I

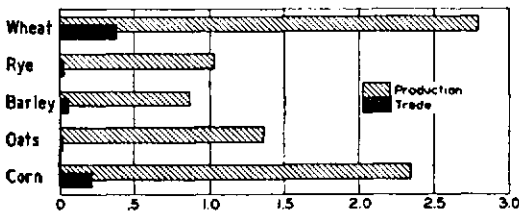
INTRODUCTION

Wheat, rye, barley, oats, and corn play widely different roles in world production and world trade. As Chart I shows, world production of wheat is more than three times as large as that of barley. Corn occupies almost as commanding a position as wheat, while world production of rye exceeds that of barley by a few per cent only. Oats hold an intermediate position, with production not quite half so large as that of wheat. The data on production presented in the chart are unfortunately incomplete; but inclusion of China and other omitted countries would enhance the dominating position of wheat and further diminish the relative importance of the other four grains, particularly oats and rye.

The differences between the grains in the amounts traded internationally are even more striking. Aggregate net exports of wheat (including wheat flour) are more than half of the total trade in all five grains. About two-thirds of the remainder is trade in corn. Of the world total the share of

CHART I.—WORLD PRODUCTION AND WORLD TRADE IN FIVE GRAINS, AVERAGES FOR CALENDAR YEARS 1931-35*

(Billion cents of 100 pounds)



* Data from *International Yearbook of Agricultural Statistics, 1935-36 and 1936-37* (International Institute of Agriculture, Rome, 1937). As in Appendix Tables I to III and V, which give details but for different periods, "world" production excludes crops in China and a few countries of relatively small production for which satisfactory data are not available, and "world" trade is measured in terms of aggregate net exports of most net-exporting countries.

barley is about one-fifteenth, and that of rye and oats together is not larger than that. Moreover, the five grains differ substantially even with reference to the proportions of total production moving in international trade. In the five years for which data are presented in Chart 1, net exports of wheat (including wheat flour) were equivalent to about 12 per cent of the world production, while only about 2 per cent of the world output of rye and oats passed in international trade.

SCOPE

The purpose of this study is to indicate the major influences responsible for the present distribution of world production and world trade among the individual grains and the major long-run changes in this distribution. To fulfill this task the competitive position of each grain must be studied in the spheres of both consumption and production.

An immense literature is devoted to this subject. It is so huge that the writer cannot pretend to have made the acquaintance even of all the important publications relating to it. Particular attention to the subject is given in almost numberless investigations in economic geography, agricultural marketing, and farm management, because soil is by far the most pertinent of natural resources and grains constitute the most important group of plants grown on the soil.

Geographers habitually discuss their subjects very broadly, both with regard to coverage of stages through which goods pass from production to consumption, and with reference to territory covered. They tend, in fact, to discuss all phases and to cover the whole world. But they display an inclination toward descriptive presentation, and are mostly satisfied with general statements in so far as causal relations are given attention. Statistical data are rarely presented and are usually intended as illustration rather than proof.

Students of markets naturally concentrate on the final stages through which the goods pass. Competition for markets, and for ultimate consumers, is elaborated in detail,

while the production phase gets only passing attention. These studies are usually international with regard to territory covered, but countries without either large exports or large imports are for the most part disregarded.

Farm management studies display characteristics opposite to those on agricultural marketing. In them, competition for the consumer gets even less attention than is true of the initial phases in studies of agricultural marketing. Farm management studies also are almost all purely of local validity, at most considering conditions of a whole country but usually covering a region of tiny dimensions. Within these limits, competition for the land receives the most thorough analysis, not merely in general terms but frequently in pounds and cents.

The writer has desired to combine the precision of the farm management studies with the breadth of the investigations in marketing and geography. But it is the fate of desires to remain unfulfilled. Sacrifices proved inevitable. The writer was most unwilling to make sacrifices at the expense of precision. He felt also that for the goods studied all phases should be covered. Consequently, the larger sacrifices were necessary with regard to both the number of goods and the number of countries covered.

To find space for a rather detailed analysis of both production and marketing phases, the study had to be limited to a few goods only. The actual content of the book in this regard is narrower than is indicated by the title. The term "grain" as here used refers specifically to only five grains: wheat, rye, barley, oats, and corn; and attention is directed principally to the production of these crops for grain rather than for hay, silage, and pasture. The study is furthermore primarily concerned with the occidental parts of the world's temperate zones. Even within this territory, countries not participating in world trade could in general be given only passing attention.

In spite of these limitations, the subject chosen appears to

be sufficiently comprehensive to permit isolated treatment. Grains (including others than the five here treated) represent much the most important source of carbohydrates in concentrated form, for both man and beast. All other important carbohydrates used as feed are much cheaper and bulkier per weight unit than grains. Hence, though grains too are rather cheap and are predominantly consumed locally, they represent the flexible fraction of the feed ration of domestic animals. While grains are more or less distinctly separated from other goods or groups of goods in their role as consumers' goods, within the group there are far-reaching possibilities for the substitution of some grains for certain, though not all, others. In the past each grain has been used in substitution for any other. Thus at the consumption end we have a more or less specific group of goods.

Since carbohydrates, together with fat produced by domestic animals from carbohydrates, make up a large portion of the human diet, grains dominate agricultural production. They are the only crops produced in some important agricultural regions. In a further large group of regions, crops other than grains play only a secondary role. But even where grains are relegated to a less significant position, their role can frequently be studied successfully without much reference to other crops, since in many rotations grains—especially the small grains—occupy specific places not suitable for other crops. The competition is therefore not so much between grains and the other crops as among the grains themselves.

The five enumerated grains, moreover, are the only ones of great import in the production and trade of the occidental parts of the temperate zones. And the production and trade of this part of the world covers by far the predominant portion of the world production and trade of these grains.

Grains not studied.—Apparently the original home of all important, if not all, grains was in very hot climates.¹ Almost all important grains have penetrated more temperate

¹ See chap. xviii, "Historical Aspects."

zones by adjusting themselves to lower temperatures during their growing season and/or reducing the growing season itself. But this adjustment and penetration vary to such a large extent with various grains that, considering the situation from the point of view of temperate zones, one is justified in designating the grains studied here, with millet,² buckwheat,³ spelt, and emmer, as the grains of the temperate climates, while classing sorghums, pearl millet, and rice as the grains of hot climates.

Spelt, emmer, millet, and buckwheat all more or less belong to the past. Spelt and emmer, primitive types of wheat, are of no significance whatever except in small localities, as portions of Bavaria, Germany. Buckwheat seems to be in large demand for food use only among the poorer classes of consumers in Russia. The food use of millet outside of eastern and southeastern Asia seems also to be limited primarily to low-income people of Russia.

Buckwheat and millet are poor yielders. Their principal advantage is that they can produce a meager crop with the most primitive cultivation and in the shortest time. In the long past this ability insured millet its position as the predominant grain of the Old World. In more recent times buckwheat and millet were—and still are to some extent—important where the equipment is inadequate to permit planting the acreage devoted to spring grains, in due time, with those that require early seeding. Buckwheat, moreover, is satisfied with the poorest soils. Nevertheless, outside of Russia, it has been pushed up into rough mountainous regions (French mountains, Appalachians, etc.). Millet finds some refuge in very hot

²The designation millet in the singular applies in moderate climates to small-kernelled millets, primarily to common millet (*panicum miliaceum*), the millet of the Old World (in the United States known as prozo, Russian millet, or hog millet), and also to foxtail millet (*setaria* or *chaetochloa italica*), the one most frequently grown in the United States. Sorghums, and pearl and bulrush millets (*pennisetum glaucum* and *pennisetum typhoideum*) belong botanically to millet in a broader sense, frequently referred to by using the plural millets.

³Buckwheat is not a cereal, as are all other plants classed as grain; but with respect to both production and use it is properly classified with this group. Otherwise the term grain should properly be reserved to cereals. To include linseed, peas, beans, lentils, and the like in the group of grains, as is done in some statistics, is misleading.

climates where more than one crop can be grown in the same year but the time available for the second crop is short. In temperate zones millet is primarily adapted to those extremely dry regions with summer rainfall which are too cold for sorghums and little adapted to any kind of crop production.

Sorghum is fairly important for the world as a whole, but mainly in the regions not covered in this study. In British India, including Indian native states, not less than 35 million acres of sorghum were grown in 1935-36. Possessing the typical characteristics of plants of very hot climates, but having the ability to shorten its growing period greatly without largely reducing the yield, this extremely modest and yet prolific plant has invaded all of the monsoon region of Asia up to Japan and Chosen. In Africa it likewise extends south and north of the tropics. Around 1875 the type of sorghum designated in the United States as grain sorghum entered this country, and displaced corn from much of Texas and Oklahoma, a portion of Missouri, southwestern Kansas, and some territories farther west, as far as California. It has recently invaded Nebraska and continues to spread, at a less rapid rate, as adapted varieties are found and as feeders overcome their mistrust of its feeding value.⁴ Attention is now being given to sorghum in Russia also, as a plant adapted to the driest and hottest portions of the southeast. Though the outcome of introduction of sorghums in the temperate zones is difficult to foresee, this crop can hardly be expected to play an important role in the occidental parts of those zones, except locally.

Even more than sorghum, rice is a crop of the hot climates. A little is grown in Italy as far north as the Po valley. In northern Hokkaido in Japan, as well as in Chosen, rice is grown even north of the isopleth of 100 average frost-free

⁴ Aside from grain sorghums, a type which includes kafir, milo, feterita, etc., and can probably be defined properly only by exclusion of the other sorghums, saccharine sorghums under the name sorgo are grown in moister regions of the United States as forage or for syrup production, penetrating as far north as Wisconsin but nowhere being of greater importance. Broomcorn and sudan grass also are sorghums, but are not included under this name in the statistics of the United States.

days.⁵ But the climatic conditions of the Po valley and the economic conditions of rice-growing in Japan and Chosen are exceptional. The huge world production of rice⁶ is almost confined to the monsoon area of southeastern Asia.

Buckwheat moves very little in international trade, while the only sizable trade in millet and sorghum is apparently exports from Manchukuo to Japan, Chosen, and China. Many countries, within the territory primarily covered in this study, import small to moderate quantities of rice. Rice trade is of substantial importance only among countries of southeastern Asia which are its major producers. The Orient is a world by itself, with its own climate, diet, and economic and social setup, and this makes it rather easy for us to omit it. The inclusion of rice would mean the discussion of two worlds. The writer would be satisfied to have mastered one.

Territory not studied.—Outside of the occidental parts of the temperate zones, rye and oats are not produced in quantities worth mentioning. Wheat and barley, which—along with corn—are grown in those regions in substantial quantities, are largely produced under conditions excluding competition with the grains of hot climates. They are grown in regions ranking geographically as hot climates either at high elevations (i.e., actually in moderate climates), or else in the cool season. The competition with rice, the principal grain crop of hot climates, is limited also by the fact that the large amount of water needed by rice makes production of wheat and barley impossible. Where the cool season is too cold and/or too dry for rice, fall-sown wheat or barley is frequently rotated with it on the same land and in the same crop year. There is also, in the hot regions, little competition of wheat and barley with sorghum and pearl millet, the other hot-weather grain crops. Competition, in fact, is primarily between wheat and

⁵ R. B. Hall, "Agricultural Regions of Asia: Part VII—The Japanese Empire," *Economic Geography*, January 1935, XI, 41.

⁶ It is substantially larger than that of wheat in terms of wheat grain and rice in the hull, and may be somewhat larger even in terms of white wheat flour and white rice.

barley themselves for the land or place in rotation adapted for neither rice nor sorghum and pearl millet. The conclusions derived from the analysis of the competition between fall-sown wheat and fall-sown barley in temperate zones are largely applicable to the situation found near the equator.

Corn likewise competes little with rice, not because it could not be grown successfully on some of the lands now devoted to rice (much rice land is too wet and/or too hot for corn), but because corn is too weak a competitor in southern and eastern Asia where rice is primarily produced. Corn becomes a serious factor in the competition for land almost exclusively where there is not enough heat and/or moisture for rice or where the topography is too rough for it and the supply of labor is not so enormous as to bring about the conversion of steep mountainous slopes into an endless number of terraces.⁷ So far as there is competition, it seems to be primarily between corn and upland rice, which yields much less and usually also is of poorer quality than paddy rice or the rice grown on submerged land. The principal competitors of corn in hot climates are sorghums and pearl millets, in spite of material differences in their soil and climatic adaptability.

Exclusion of the monsoon area in Asia from our analysis makes it possible to limit the discussion of barley to the common or hulled varieties. More than half of the substantial barley area in Japan is in naked barley. Naked barley seems to be important also in Tibet and British India. But only negligible quantities are produced elsewhere.⁸ Naked barley is greatly preferred to common barley for human food in regions where simple preparations of cracked, crushed, or whole kernels are used.⁹ But the climatic requirements of naked

⁷ Samuel Van Valkenburg ("Agricultural Regions of Asia: Part IV—India," *Economic Geography*, April 1933, IX, 127) writes on the situation in India: "It [corn] achieves its chief importance in some of the northern mountain areas where the summer rains are adequate and regular, but where there is little level space for the cultivation of rice. For the same reason it becomes the principal food in a limited portion of the northwestern Deccan north of the Narbada Valley . . ."

⁸ See C. L. Alsberg, "Japanese Self-Sufficiency in Wheat," *Wheat Studies of the Food Research Institute* (hereafter referred to as *Wheat Studies*), November 1935, XII, 61.

⁹ *Ibid.*, p. 75.

barley are not readily satisfied, and it yields materially less than hulled barley, even where the climate is favorable.

Regions lying outside the occidental parts of the temperate zones are much less important with regard to international trade in the five grains studied than with regard to their production. For a few decades, British India exported large quantities of wheat and smaller quantities of barley, and in some years such movements are still of some importance. At present, other participation of those regions in world exports of these five grains consists mostly of small shipments of corn from Indo-China. Small quantities of wheat flour are imported by many tropical countries. China, not covered in this study, is in some years a rather important importer of wheat flour.

In spite of the various roles of our five grains in zones other than the occidental parts of the moderate climates, the comprehensiveness of the study with regard to coverage of the positions of the grains of moderate climates, in the world as a whole, is deficient mainly in that the position of corn in hot climates has not been adequately treated.

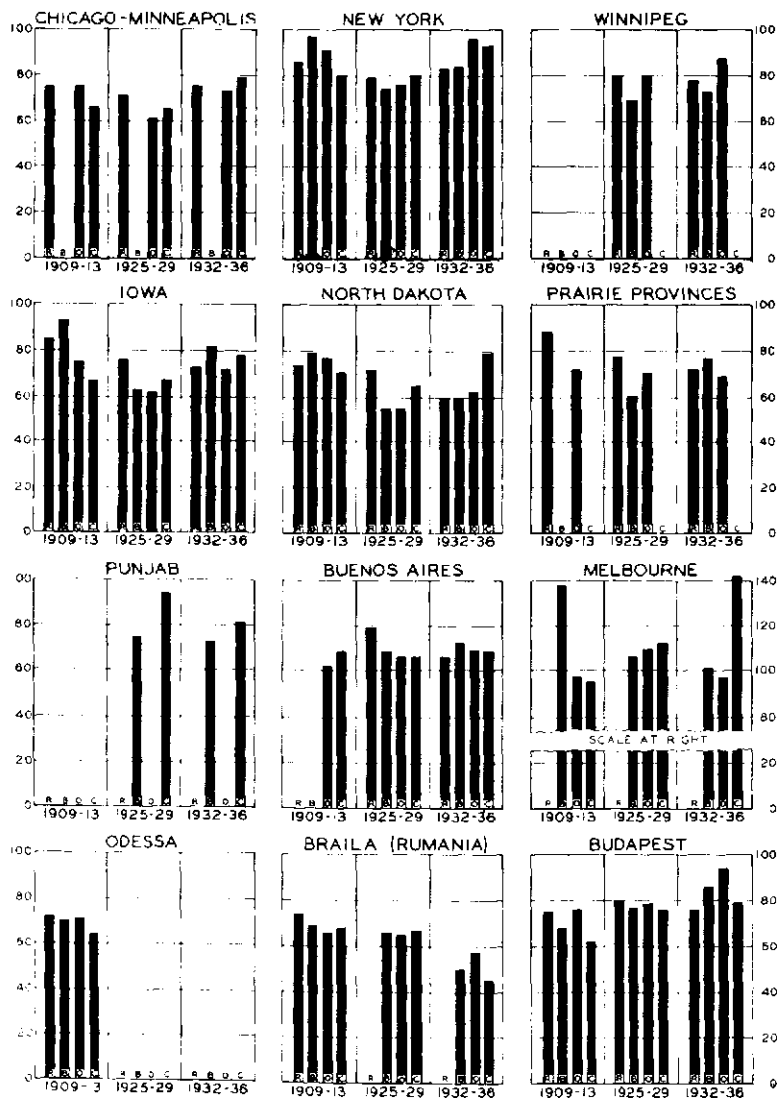
ORGANIZATION OF THE STUDY

Farmers are guided in the selection of grains they produce by the comparative advantage of growing some specific grains and the relative prices they can get for them. Ratios between costs and between prices of different grains are obviously of much greater significance in these decisions than spreads in dollars or cents.

It is not commonly recognized how large are the regional variations in the ratios between the prices received by farmers for their various grains. In some places, the highest priced of the locally produced grains is twice or more than twice as expensive as the cheapest, while in some others the range of prices of all grains is merely 10-15 per cent (see Charts 2 to 4). These differences obviously exert an immense influence on the competition of the different grains for the land.

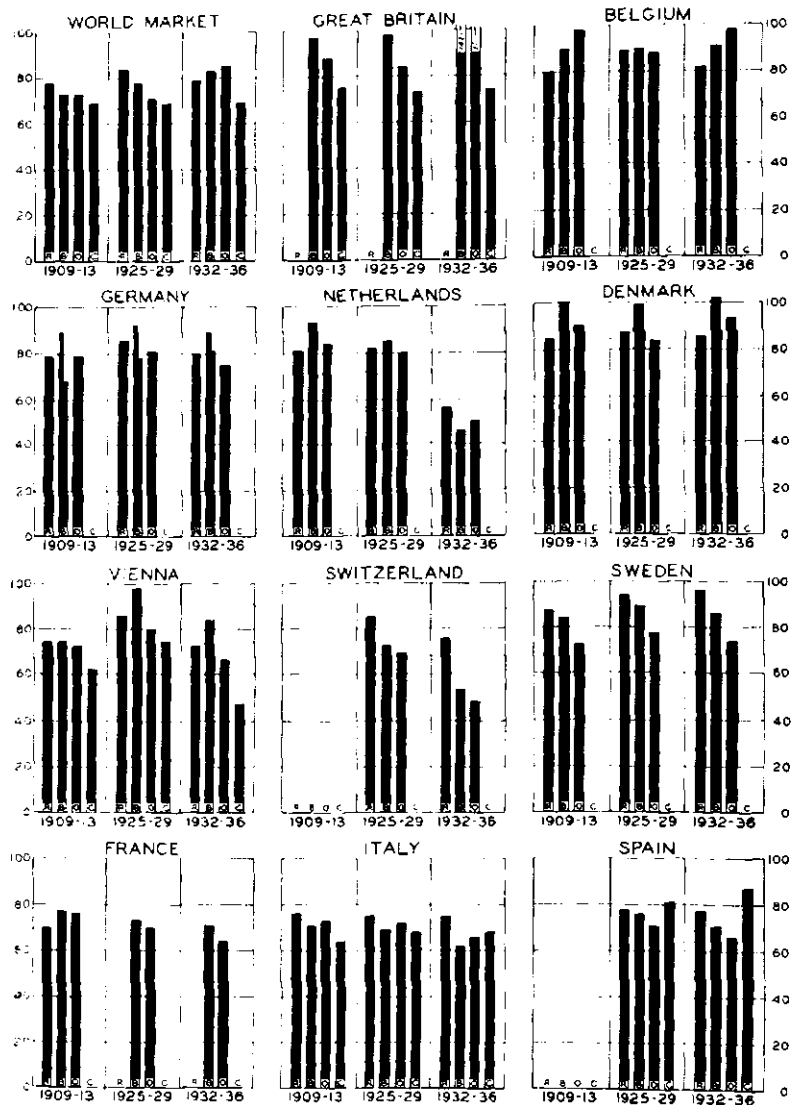
COMPETITION AMONG GRAINS

CHART 2.—PRICES OF SPECIFIED GRAINS AS PERCENTAGES OF WHEAT PRICES, IN SELECTED SURPLUS REGIONS, BY FIVE-YEAR PERIODS, PREWAR AND POSTWAR*



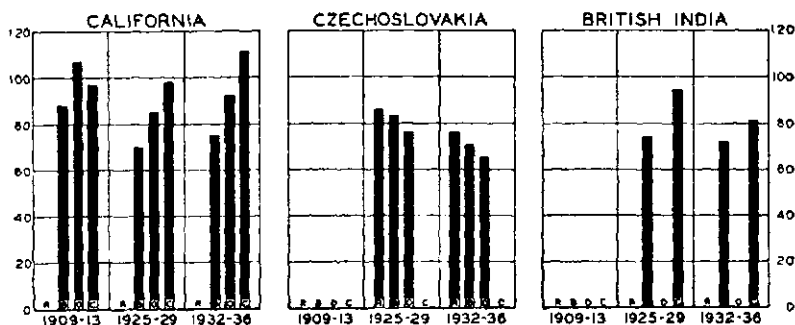
* See notes on p. 12.

CHART 3.—PRICES OF SPECIFIED GRAINS AS PERCENTAGES OF WHEAT PRICES, IN SELECTED DEFICIT REGIONS, BY FIVE-YEAR PERIODS, PREWAR AND POSTWAR*



* See notes on p. 12.

CHART 4.—PRICES OF SPECIFIED GRAINS AS PERCENTAGES OF WHEAT PRICES, IN SELECTED INTERMEDIATE REGIONS, BY FIVE-YEAR PERIODS, PREWAR AND POSTWAR



NOTES FOR CHARTS 2 TO 4

Except as otherwise stated, the basic data were drawn from official sources, the International Institute of Agriculture, Rome, and the Institut International de Statistique, La Haye. Unless otherwise stated, they are for calendar years. Percentages were computed from prices in terms of units of equal weight.

The subdivisions of countries (or regions) into surplus, deficit, and intermediate countries cannot be made exact; e.g., Hungary was a deficit country in corn in 1932 and 1935, and Germany exported rye in the prewar period. New York was included with surplus regions owing to considerations of space.

It could not always be ascertained whether the prices are market or farm prices. Moreover, the quality of the grains for which prices have been given is mostly unknown or difficult to ascertain. Barley prices are mainly averages of prices of all kinds of barleys in unknown proportions. For the world market and Odessa, they were considered to pertain to feed barley, although they were not so designated officially. The same may be reasonably assumed with regard to North Dakota barley and some others.

Chicago-Minneapolis.—No. 2 Red Winter Wheat, No. 3 White Oats, and No. 3 Yellow Corn at Chicago; No. 2 Rye at Minneapolis. Simple averages of weighted monthly prices for August-July years beginning in the calendar year specified. Barley prices have not been included, owing to the absence of a series which could be accepted as referring to a specific type of barley.

California, Iowa, New York, and North Dakota.—Averages of prices received by producers on the fifteenth of each month, August-July crop years.

Winnipeg.—No. 3 Northern Manitoba Wheat, No. 2 Canadian Western Rye, No. 3 Canadian Western Barley, and No. 2 Western White Oats. Prewar prices have not been included, because for wheat only prices of No. 1 Northern Manitoba Wheat are available. August-July crop years.

Prairie Provinces.—Average prices received by producers in each crop year.

Victoria, Australia.—Average seasonal prices received by producers. In 1909-13 average prices received in February and March of each year. The compilers subtracted from the prices realized by the producers various outlays such as for bags and fertilizers (not the same in different years).

Punjab, British India.—Harvest prices for crop years.

Budapest, Hungary.—From *Vierteljahrshefte zur Statistik des deutschen Reichs*.

Braïla, Rumania.—Prewar prices are averages for Braïla, Constanza, Bucharest, and Galatz.

World market.—Average British import prices except as follows: (1) barley—prewar prices averages for Russian and Danubian only, and postwar prices for Russian or

The idea is widely held that wheat does relatively well in regions inadequately supplied with moisture. But the costs of producing wheat in some such regions, including those producing the largest surpluses of wheat in the world, are most unfavorable for it, relative to the costs of some other grains grown in the same regions. The real cause of the supremacy of wheat there is that wheat prices exceed the prices of the other grains by 50 per cent or more. In very important deficit regions, on the other hand, wheat, unless protected by tariffs more than the other grains, has to compete for a place in production with a price advantage in its favor of only 10-15 per cent and sometimes none at all.

The basic cause for the existence of differences in the prices received by producers—whether measured in dollars and cents or in ratios—is preference of consumers for certain grains for specific uses. The discussion therefore begins with an analysis of the suitability of our five grains for various uses (chapter ii). In chapter iii the attempt is made to rank the grains according to consumers' preferences in various uses in different countries. Chapter iv is devoted to a closer analysis of the elasticity of demand, and of the extent of substitution of one grain for another, which determine the position of the grains in the scales of consumers' preferences.

But preference of consumers for certain grains for specific uses is only one of the factors determining the size of

Danubian at Rotterdam; (2) rye—prewar prices for Russian at Bremen, and postwar prices for imported rye at Rotterdam. On the average, British imports of oats in postwar years probably consisted of more valuable types and grades than the prewar imports.

Great Britain.—Gazette average prices except those of corn, which are for La Plata Yellow Corn.

Germany.—Carload prices in the province of Brandenburg (Berlin the capital). The left side of the bars for barley refers to malting barley and the right side to feed barley.

Netherlands.—Crop-year prices (August-July) in the province of Groningen.

Vienna, Austria.—From *Vierteljahrshefte zur Statistik des deutschen Reichs*.

France.—Paris prices.

Italy.—Prewar prices for Milan. Wheat prices for common wheat, not durum.

Spain.—Instead of 1932-36, prices of 1930-33 have been used.

Prague, Czechoslovakia.—Instead of 1932-36, prices of 1931-35 have been used.

South Africa.—Instead of 1932-36, prices of 1931-35 have been used.

the ratios between the prices received by farmers for their various grains. Other factors usually strengthen, but sometimes counteract, its effect. No regional divergences in consumers' preferences for specific grains, for example, are involved in the large differences between the price ratios of wheat and the other grains in certain important surplus and deficit regions mentioned above. Hence the effect of factors other than consumers' preferences on the price ratios in that case is several times as strong as that of the mere preference for wheat as such.

The degree to which different types of the same grain satisfy consumers varies. The adaptability of different regions to produce grains of specific qualities varies also. One grain produced in a certain locality satisfies the qualitative requirements for that particular grain and therefore commands high prices within its kind. Certain other grains produced in the same locality may be of less desirable types within their specific kinds. In the above example of the large differences between the price ratios of wheat and other grains in certain surplus and deficit regions, the surplus regions produce an excellent wheat, while the deficit regions can grow only wheat of poor quality. Thus differences in the adaptability of different regions to produce grains of certain qualities become an important factor bringing about regional differences between the ratios of grain prices.

Furthermore, the prices received by farmers and paid by consumers are made to differ by marketing charges and import duties. Since grains are relatively cheap, marketing costs bring about substantial regional price differentials, and regional price differentials caused by import duties are frequently even larger nowadays. It is particularly important to note that regional price differentials tend to be strongly reflected in the ratios between the prices of different grains in the same localities. This is at least true of marketing costs. Such effect of marketing costs, for example, is the second contributing factor bringing about the large differences be-

tween the price ratios of wheat to other grains in certain surplus and deficit regions mentioned above.

In spite of the great importance of regional variations in the price structure, only marketing costs are considered in some detail in this study. As to import duties and qualitative differences of grains produced in the same localities, it has been felt that they do not need much elaboration. Chapter v discusses the effect of the quality of the locally produced grains on the ratios between the prices of different grains at the same places, while in chapters vi and vii the effect of marketing costs and import duties on the same ratios is treated. A short sketch of the changes in price ratios between different grains in the past in chapter viii concludes the first part of the study.

Part I in spite of numerous shortcomings appears to provide a reasonably precise account of the relative prices of different grains at different places at present and in the past, of the reasons which bring about these differences, and of the possible changes in them in the future, so far as these changes may originate from the demand side. Unfortunately, no corresponding degree of precision can be attained in the analysis of the relative position of different grains with reference to their cost of production.

The computations of the absolute costs of production of goods, and also of the more reliable ratios between the costs of production of different goods, involve so much arbitrariness that conclusions based upon them must necessarily be more or less indefinite. The difficulties are particularly great with reference to costs of crops which are mostly grown in rotations, i.e., as supplementary goods, and are also frequently interconnected with animal husbandry as users of manure and suppliers of feed. Moreover, the charge for land use, which makes up a substantial amount of total costs, not only mostly represents a joint cost but depends also on the prices of the crops themselves, i.e., on a factor which in turn depends on the cost of production. Fortunately, the differences in the

yields of different grains obtained from the same land are in general the most important single factor bringing about differences in the costs of production; in the competition for the land, they are frequently decisive and always very important. It therefore seemed advisable to begin the analysis of conditions of supply with a consideration of yields. A clear view of the ratios between the yielding capacity of different grains on the same land contributes much toward an understanding of their competitive power.

The natural factors that are largely responsible for differences in yields of different grains in the same locality display an almost infinite number of combinations. Hence discussion of the yielding power of different grains under different conditions necessarily becomes rather lengthy. Accordingly, the whole of Part II is devoted to it, in spite of the fact that logically the costs of production as a whole and not one element of them represent the counterpart of Part I. The first chapter of Part II (chapter ix) begins with a discussion of differences in the inherent yielding capacity of different grains; next it treats the rather important variations in the proportions of straw to grain in different grain plants under different conditions; and it concludes with a discussion of the implications involved in the analysis of the statistical and experimental data on yields. Chapters x, xi, and xii treat the respective effects on yields of soil, temperature, and moisture, while in chapter xiii the differences in the response of the grains to cultural practices are considered. Part II closes with a brief discussion of the development of agricultural technique in the past.

Part III deals with the differences in the cost of production of the grains. The peculiar character of the cost-of-production data warrants a lengthy discussion of the value of such data which constitutes Appendix Note C. The differences in the cost of production of different grains per acre are taken up in chapter xv and the differences in the cost per cental in chapter xvi.

The reader will have noticed that up to this point, the organization is a rather unusual one. The most common organization in dealing with crops—whether written by agronomists, geographers, or economists—is to take up the crops one by one, discussing for each of them separately all points regarded as necessary. This procedure has an advantage of giving a comprehensive picture of each crop. But it leaves the reader—and perhaps the authors as well—undecided as to the true reasons for the production or use of this crop and not another. Such decisions are especially difficult to make where one crop does not fully predominate but has only an edge over the others.

Factor by factor rather than grain by grain is in general the course of treatment in Parts I to III of this study. In the chapter on "Temperature," for example, winter-hardiness, minimum germinating temperature, total warmth requirement, resistance to heat, and so on, are separately discussed, dealing under each with each of the five grains. Such procedure involves much extra work. Data permitting reliable comparisons of the effect of each factor on each grain are not always easy to procure and in some cases are not available. The results nevertheless are well worth the trouble, in the opinion of the writer. Where, owing to lack of data, a comparison could not be made, a frank acknowledgment may induce research to fill the gap.

To compensate for the scattering of the data pertaining to each grain over the whole text in Parts I to III, Part IV, except for its first chapter, returns to the usual organization by grains. This part is an integration of the findings of Part I with those of Parts II and III, supplemented by additional data.

Chapter xvii presents a summary picture of the competition among grains in its vertical, horizontal, and historical aspects. Chapters xviii to xxii deal with the findings for each grain separately—beginning with corn, proceeding to wheat, rye, and barley, and ending with oats. To avoid repetitions,

only the chapter on corn gives a reasonably rounded presentation. Each consecutive chapter contains numerous references to preceding chapters. The development of world trade, for example, is discussed under "corn" for feed grains and under "wheat" for bread grains.

A TECHNICAL REMARK

We have repeatedly stressed the limitations with reference to the degree of attainable precision, though all limitations have not been mentioned. Substantial uncertainties, for example, remain even with regard to the differences in yields of the grains produced in the same localities, although several chapters are devoted to this subject. There is, however, one point in which precision is easily attained but which, if neglected, invariably results in lack of clarity.

It seems that many students dealing with grain in North America may not have a clear idea of the *relation* between prices or yields of different grains. To the statements, "Oats were more expensive than wheat" or "Wheat outyielded oats," it is commonly rejoined: "This could never have occurred." The person giving the answer is accustomed to think in terms of bushels of *different* weights. Being reminded that such comparisons have no value whatever, he agrees at once and begins to rework the data on a more appropriate basis. But without such reworking he does not know the true relationship, and this relationship is not borne constantly in mind.

To realize the immense harm to clear thinking that is done by the use of bushels of unequal weight, it suffices to compare the publications of the California Agricultural Experiment Station with those of a station in the East, the Department of Agriculture, or the Bureau of the Census. How simple and illuminating, for example, is the information obtained by the writer from Professor R. L. Adams of the University of California, that the "usual" yields¹⁰ of wheat, barley, and corn

¹⁰ Professor Adams distinguishes "usual," "good," and "outstanding" yields.

on irrigated land in California are 1,200, 1,500, and 1,500 pounds per acre, respectively, as compared with a statement that the yields of those grains are equivalent to 20.0, 31.25, and 26.8 bushels.

Comparisons of yields or prices of different grains are made in this study solely on a basis of units of equal weight. The unit most frequently used is the cental of 100 pounds, for which there is some sanction in trade usage and which lends itself to ready conversion into short tons of 2,000 pounds. Although some readers will have difficulty in getting used to this form of presentation, the effort will not be wasted.

PART I

USES AND PRICE RATIOS

CHAPTER II

THE USES OF GRAINS

GENERAL ASPECTS

In a very broad view of the utilization of grains in the past, one general tendency clearly emerges: a gradual shift from exclusive use for human food and drink to utilization of an ever increasing portion for feed. Concomitantly, an ever rising proportion of the land has been devoted to the production of feed crops (grass, roots, etc.). Thus indirect utilization of the produce of the soil is gaining at the expense of direct utilization. A similar picture, in a geographical rather than a historical aspect, is perceived if one compares the situation in an extremely poor country with that in a rich country. For example, very little acreage usable for food production is devoted to feed production in China,¹ whereas in the United States only about 27 per cent of the grain domestically consumed is used for food,² and an immense acreage is devoted to the production of feed not in the form of grains.

If grain is used both as food and feed, men have the alternatives of using for each purpose a portion of each of the available grains and of using some grains for food and some others for feed. Though no grain has entirely ceased to be used as food, general development has been in line with the second alternative. One by one, grains are losing their significance either as food or feed, and the distinction between food and feed grains becomes ever more pertinent.³ More-

¹ There, about 10 per cent of the total production of all grains has been used for feed in recent years. China, Department of Agricultural Economics, National Agricultural Research Bureau, Ministry of Industries, *Crop Reports*, Aug. 1, 1934, II, 70-71. Such use of grain for feed as is found in China is mainly concentrated in the north.

² U.S. National Resources Board, *Agricultural Land Requirements and Resources, Part III of the Supplementary Report of the Land Planning Committee to the National Resources Board*, 1935, pp. 23-27.

³ Those grains can be classed as feed grains for which the demand for food is so small compared to the total available supply that the use as food does not sensibly affect prices, which are determined in the feed-grain rather than the food-grain market.

over, specific roles within each broad group of uses have been more and more assigned to specific grains, and even to specific types or grades of some specific grains.

The use of substantial amounts of grain as feed is of rather recent date. Consequently, the definite relegation of some grains to the position of feed grains is a comparatively new phenomenon. As late as the early twentieth century, Russian statistics listed oats as the only nonfood grain and included in the food group wheat, rye, barley, corn, buckwheat, millet, peas, beans, and lentils.⁴ The proportion of barley used in Russia for food (other than drink), it is true, had dwindled almost into insignificance in the decades just before the World War, but buckwheat and millet even now retain their position of food grains and may preserve it for a rather long time. In the Indian statistics all grains are found under food crops.

Oats, in fact, are the only grain which have no great importance for use as food in at least one larger country. Corn is the principal or at least an important food product in substantial parts of Asia, Africa, and Central America; in the Danube countries and parts of Italy, Spain, and Portugal; and even in a portion of the United States. Barley is the staple grain food in large portions of northern Africa and Asia. Moreover, suitable qualities of barley have monopolized the use as raw material of beer; but malting barley⁵ in the economic sense is almost a separate grain, distinct from all other barleys. If the grouping in food and feed grains is made from the point of international trade, corn and barley (other than malting) belong with oats in the group of feed grains, while wheat, rye, and malting barley are the principal food grains. In a not very large but very important portion of the world, wheat is the only significant grain in the use for food

⁴ See, for example, Russia, *Direction générale de l'Organisation agricole et de l'Agriculture, Division d'Economie rurale et de Statistique agricole, Recueil de données statistiques et économiques sur l'industrie agricole en Russie et dans les pays étrangers* (Petrograd, 1915), 8th year, pp. 6-7.

⁵ The expression malting barley will be used to designate barley used in beer preparation.

in the narrow sense, and all other grains (except malting barley) have been degraded to the position of feed grains. This area in the main comprises the northwestern fringe of Europe (Great Britain, France, Belgium, the Netherlands), Switzerland, large parts of Italy and Spain, Australia, most of North America, and the wheat-growing parts of South America.

Though displaying some peculiarities, all grains are rather similar in the kind and amount of nutrients they contain, and in nutritive value. If these were the only factors considered by consumers, the possible substitution of one grain for another would be almost unlimited, and the prices that consumers would be prepared to pay would be approximately equal for all grains except oats. But an unlimited substitution exists now only with regard to the use as raw material for alcohol as used for most technical purposes. In general, each grain or group of grains is preferred for some specific use. These preferences bring it about that consumers are prepared to pay more for one than for another.

Only wheat and rye doughs can retain large quantities of gases in the baking process, and this property is less in rye than in wheat. Oats are particularly appropriate for horse feed. Barley produces pork and fat of the highest quality. There are further differences in palatability, digestibility, appearance, and the like. All these differences are caused by objective properties of the grains and the specific character of the uses. But in the final analysis it is not these objective differences that are responsible for the extent of the possible substitution of one grain for another, but rather the importance assigned by consumers to the differences in degree of perfection with which different needs are met by different grains, as well as the ability of consumers to pay for their preferences.

Whenever and wherever they can afford the expense involved, men demonstrate readiness to make great sacrifices in order to have the specific foods and in the specific form preferred. In the realm of Western civilization, for example,

people insist on eating most of their cereals in the form of bread. A baked product, very insufficiently aerated but similar to wheat bread in nutritive value and palatability, is produced from corn, yet corn is not considered by most consumers to be an adequate material for breadmaking. For this purpose even rye flour, which can retain gases in the baking process, commands only second place; it is easily displaced in the long run by wheat, but by no other grain, while the extent of displacement of wheat by another grain in breadmaking is extremely narrow. The same is true of barleys adapted for beer preparation. The substitution of one type of porridge for another is likewise vigorously objected to, and in some countries the extent of substitution of one grain for another for this purpose is practically nil.

There are also distinct preferences for certain grains for specific uses as feed. But in general and especially in the long run, the preferences for certain feeds are far less persistent than those concerning use for food, and the reasons for preferences are less subtle. The lesser adaptability for certain uses as feed is much more readily disregarded. The form in which the grains are used—so important for the use as food—commands very little significance in the case of feed. The problem is solved simply by feeding each grain in the form in which best results (from the point of view of the feeder) can be expected. Some grains are fed whole, some crushed, and some at times cooked.

The long-time development leads to displacement of part of the cereals in the diet by other foods. But over shorter periods, substitution due to price changes is extremely limited and in many countries nonexistent. In feed use, however, substitution of other feeds for or by grains occurs much more readily. Furthermore, changes in consumption of specific grains as food under the influence of price variations, without substitution for or by another grain or another product, are far less than in the case of the use as feed. Death from starvation of human beings is comparatively rare, but ad-

justing livestock numbers to changing amounts of available feed is a regular procedure, especially in some regions. Thus in the use of feed we have larger substitution of one grain by another, larger substitution of feed grain for and by non-grain feed, and larger contraction or expansion without any substitution.

The use of grains as food must therefore be considered as ranking higher in consumers' preferences than the use as feed. This means the possibility of much higher prices for food grains and even of larger price divergences between different food grains. The possible price divergences between different feed grains, so far as they are determined by the preferences of consumers, are much smaller.

The means of men have increased with the passage of time. Hence, time has worked in the direction of ever lessening substitution of one grain for another in food use. In the more distant past, the predominant part of mankind was compelled to be satisfied with any kind of grain available, and the degree of substitution between them was very wide, nearly perfect. Larger means now permit men to be more selective also in the feeds they give to animals, but except for pets they make little use of this opportunity. In some cases they probably choose to do so to an ever lessening extent, owing to the spread of knowledge on rational feeding that has made increasingly clear the large degree of substitution possible in the use of grains for feed.

The extent of substitution of one grain for another seems to be the most important factor determining, from the demand side, the distribution of the world production and world trade among different grains. Where substitution of one grain for another occurs readily, the special adaptability of a grain for some particular use is given little weight; over long periods the conditions of production are decisive for the choice of grains produced. Consumption tends to be adjusted to the supply. Major disturbances of the market position of grains that can easily be substituted for each other tend to be rare,

for shifts in consumption generally suffice to prevent them. Where one grain can easily be substituted for another, the grains that are consumed are predominantly those produced locally. Hence trade, and particularly international trade, tends to be limited in scope. This is the situation displayed by feed grains and, with the limitation to long-run developments only, also by rye.

Quite the reverse is observed where the possibility of substitution is absent or very small. Since consumption refuses to shift, the grains asked for are produced whatever the obstacles may be. With little or no adjustment forthcoming from the demand side, market disturbances develop much more easily. Shortages of supplies lead to price increases out of proportion to the reduction in supplies. Excessive production brings accumulation of excessive stocks, unless prices fall to such an extent that lower-ranking uses become practical. So far as this does not occur, contraction of production is the only means of eliminating excessive stocks. Since the possibility of substitution is absent or limited, the kinds of grains wanted have to be brought from distant regions if they cannot be produced locally. Trade, particularly international trade, tends to be large. This is notably the case with wheat. It is less true of malting barley, for the distinction between malting and other barley is somewhat elastic and most consuming areas can produce what malting barley they need.

PHYSIOLOGICAL ASPECTS

Three different "stages" can be distinguished with reference to the nutritive value of grains: (1) the amounts of nutrients contained in the food or feed, (2) the amounts that can be digested, and (3) the amounts which after having been digested are made available for sustaining the lives of animals, for increasing their weight, for work, for producing milk, wool, or offspring, and the like (Table 1, p. 30). This third "stage" represents the so-called net energy value.

The difference between the total nutrients and the diges-

tible nutrients is voided, and does not enter the body tissues of the animal. The difference between the digestible nutrients and the so-called net energy value is used for the digestive process proper. The heat developed in this process is an asset in winter but may become a burden in the hot season.

The net energy value—with some exceptions the most important factor—is not extensively used in this country for comparisons of the nutritive value of different foods and feeds. The reasons brought forward are that net energy values are laborious to determine, and that they vary substantially for various animals and for the same animals under different conditions.^a Kellner's starch equivalents (Table 2), however, are very similar in character to net energy values, and seem to have been widely accepted by research workers and farmers in Germany and some other countries.

Chemical composition.—As shown in Tables 1 and 2, all five grains are very similar in chemical composition. Nitrogen-free extract, consisting mainly of carbohydrates, by far predominates in all. On a water-free basis, oats alone show a content of nitrogen-free substances of slightly less than 70 per cent. The content of proteins, which take second place, is far lower; even in oats, the grain with the highest ratio of proteins to nitrogen-free substances, this ratio is only about 20 to 100. Since, moreover, the low moisture content permits grain to be stored for a long time and to be transported over long distances, its chemical composition suits well for its role as the principal source of carbohydrates in concentrated form for both men and animals all over the world.

Within the general frame of similarity, however, there are some differences which affect the uses and value of each grain, in some cases very strongly. Oats and barley, as well as buckwheat and millet, retain their hulls when threshed, while wheat, rye, and most sorghums, including all varieties designated as grain sorghums in the United States, emerge from the threshing machine without them; and corn also leaves the

^a See footnote c, Table 1.

TABLE I.—AVERAGE CHEMICAL COMPOSITION, DIGESTION COEFFICIENTS, AND NET ENERGY VALUE OF GRAINS (AMERICAN DATA)*

(Per cent, except as noted)

Nutrients or coefficients	Wheat	Rye	Barley	Oats	Corn	Grain sorghum*
Total dry matter.....	89.8	90.0	90.4	91.1	88.5	89.2
Digestible proteins.....	11.3	10.3	9.3	9.4	7.4	9.3
Total digestible nutrients ^b ..	83.6	80.1	78.7	71.5	83.7	79.9
Chemical composition						
Protein.....	13.1	12.3	11.8	12.0	9.7	11.8
Fat.....	1.7	1.7	2.0	4.7	4.0	2.9
Fiber.....	3.0	2.3	5.7	10.6	2.3	2.2
N-free extract.....	70.0	71.7	68.0	60.2	71.1	70.4
Mineral matter.....	2.0	2.0	2.9	3.6	1.4	1.8
Digestion coefficients						
Protein.....	86	84	79	78	76	79
Fat.....	83	64	80	88	91	76
Fiber.....	90	..	56	38	57	54
N-free extract.....	95	92	92	81	94	91
Net energy value per 100 lbs. (therms) ^c	84.7	72.1	70.5	64.9	82.3	75.2

* Data from F. B. Morrison, *Feeds and Feeding* (20th ed., Ithaca, N.Y., 1936), pp. 976-91, 998-99.

^a Simple average of milo, feterita, and kafir.

^b Total digestible nutrients have been computed by Morrison by applying the digestion coefficients to the amounts of nutrients contained in the grain, and summing them up. The digestible fat has been multiplied by 2.25 before the summation was made.

^c A therm is equivalent to 1,000 Calories or 1,000,000 calories. The net energy value has been determined chiefly from experiments on mature steers. It is different even for dairy cows. For instance, common barley and oats for dairy cows have a net energy value of 79.2 and 71.3 therms, respectively, as against the 70.5 and 64.9 therms shown in the table.

sheller in a naked form. The hull contains a large percentage of fiber which has a very low value. Hence the average fiber content of oats on a water-free basis is about 12 per cent, while wheat, rye, corn, and grain sorghum have only 2.5 to 3 per cent of fiber. Barley occupies an intermediate position, with an average of 6 to 9 per cent of fiber on a dry-matter basis. Millet contains about as much fiber as oats, buckwheat even more.

The variations in protein content are much less than the variations in fiber content. Wheat has the largest quantities

TABLE 2.—AVERAGE CHEMICAL COMPOSITION, DIGESTIBLE NUTRIENTS, AND STARCH EQUIVALENT OF GRAINS (EUROPEAN DATA)*

(Per cent, except as noted)

Content	Wheat	Rye	Barley	Oats	Corn
Total content					
Water	13.4	13.4	14.3	13.3	13.0
Protein	12.1	11.5	9.4	10.3	9.9
Fat	1.9	1.7	2.1	4.8	4.4
N-free extract	69.0	69.5	67.8	58.2	69.2
Fiber	1.9	1.9	3.9	10.3	2.2
Mineral matter.....	1.7	2.0	2.5	3.1	1.3
Digestible nutrients					
Protein	10.2	9.6	6.6	8.0	7.1
Fat	1.2	1.1	1.9	4.0	3.9
N-free extract	63.5	63.9	62.4	44.8	65.7
Fiber	0.9	1.0	1.3	2.6	1.3
Starch equivalent per					
100 lbs. (pounds)*	71.3	71.3	72.0	59.7	81.5

* Data from O. Kellner, *Die Ernährung der landwirtschaftlichen Nutztiere* (10th ed., Berlin, 1924), p. 640.

* The starch value has been computed by Kellner by reducing the content of digestible nutrients to equivalent starch units, assuming one unit of digestible protein to be equivalent to 0.94 units of starch and one unit of digestible fat to be equivalent to 2.12; and by multiplying the sum of all items by an "effectiveness-factor"—for corn, 1; for barley, 0.99; and for wheat, rye, and oats, 0.95.

of protein, corn and barley the smallest, with rye and oats occupying intermediate positions. While the variations in the amount of protein are too small to exert a large effect on the value of different grains, the types of the proteins contained in different grains show divergences that are of great importance for the value of all grains. The adaptability of grains for the preparation of bread, the use of commanding importance, depends on the presence of specific proteins which wheat, and to a lesser extent rye, alone possess (see below, pp. 41-42).

Variations in fat content are relatively much larger on a percentage basis than variations in the content of protein, though not much more important. The fat content of oats exceeds that of the other three small grains by 100 to nearly 200 per cent, and corn too has at least twice as much fat. The

TABLE 3.—CHEMICAL COMPOSITION OF DIFFERENT PORTIONS OF THE WHEAT AND RYE KERNEL*

(Per cent)

Product	Mineral matter	Fat	Protein	Carbohydrates			Pentosans ^a	Percentage of dry matter ^b
				Sugar	Starch	Fiber		
WHEAT								
Whole kernel.....	1.92	2.29	15.49	5.19	66.25	2.51	7.94	101.59
Finest flour (0-30).....	0.49	1.14	13.24	2.14	79.29	0.12	2.59	99.01
Second flour (30-70)....	0.88	1.86	15.08	4.67	74.69	0.20	3.37	100.75
Third flour (70-75).....	2.36	4.04	19.36	8.50	61.13	1.05	5.52	101.96
Shorts ^c	3.32	4.63	20.35	9.97	47.18	3.09	11.62	100.16
Fine bran (80-89).....	5.82	5.38	18.30	9.02	15.65	9.75	22.52	86.44
Coarse bran (89-93)....	7.59	5.15	17.39	8.56	8.74	11.33	30.49	89.25
Outer bran (93-98.5)....	7.54	5.18	17.39	8.67	14.14	9.69	29.32	91.93
Germ.....	5.50	12.00	40.75	20.75	.....	2.50	11.55	93.05
RYE								
Whole kernel.....	1.95	1.88	11.61	8.75	60.33	1.97	8.45	94.94
Finest flour (0-30).....	0.46	0.69	6.70	4.65	81.53	0.07	3.55	97.65
Second flour (30-60)....	0.94	1.43	11.00	7.18	69.44	0.40	5.25	95.64
Third flour (60-65).....	1.74	2.29	14.47	8.98	60.27	0.93	7.02	95.70
Shorts ^c	2.09	2.71	16.58	11.45	55.40	1.22	8.13	97.58
Bran (70-95).....	4.83	3.62	17.58	12.96	20.49	5.79	22.59	87.86
Germ.....	5.54	11.95	44.74	22.62	.....	3.94	7.32	91.11

* M. P. Neumann, *Brotgetreide und Brot* (2d ed., Berlin, 1923), p. 186. The figures in parentheses show the extraction in percentage of the total grain milled (as customary in most European countries) rather than in percentage of total flour (as customary in the United States). The data evidently had been obtained by milling the samples in the experimental mill of the Institute of which Neumann was one of the directors. If the samples were ground in a modern commercial mill, the differences in composition would be still more extreme.

^a A carbohydrate.

^b As determined by the analysis.

^c Middlings.

variations in the content of minerals follow those in fiber, though on a lower level. Oats have the highest ash content, and barley follows. Of the naked grains, rye has the largest ash content (European data). Variations in the content of fiber, protein, and fat to some extent offset one another. Therefore, all naked grains have about the same content of nitrogen-free substances, their fiber content being low, while the smaller content of proteins in corn is offset by its higher fat content. The larger content of fiber in barley is only partly offset by its lower protein content. Hence the content of nitrogen-free substances in barley also is somewhat less than that of the naked grains.⁷ Oats, having a high content of both fiber and fat, lag materially behind the other grains in the content of nitrogen-free substances.

All cereals are a good source of vitamins B and E but contain little vitamin G and practically none of A and D, except that yellow corn is rich in vitamin A. For a long time, it was assumed that oats contain some substance (avenin) which was supposed to exert an energy-stimulating effect on the animal body. This substance, however, has never been isolated, and its existence must now be considered extremely doubtful.

The different substances are distributed unevenly within the grain kernel. Fiber, fat, and mineral matter are concentrated in the outer portions. The amount of protein also increases considerably from the central portion of the kernels to their outer portion. The germs are particularly rich in protein, mineral matter, and fat. Table 3 demonstrates these differences clearly for wheat and rye. It does not show, however, that the highly valuable vitamins also are found primarily in the outer portions of the kernels; the finest flour is almost entirely devoid of them, as is the second flour as well.

⁷ According to Tables 1 and 2, the difference between barley and the naked grains in content of carbohydrates is very small. But feeding barley of high grade, according to Morrison, contains only 61.0 per cent of nitrogen-free substances and feeding barley of low grade 56.2 per cent. The content of fiber and mineral matter of barley as shown in Table 1 is 8.6 per cent, but feed barley of low grade has 14.7 per cent.

The distribution of nutrients and vitamins in other kinds of grains is similar to that of wheat and rye, except that the hulls retained by some grains do not differ much in composition from their straw.

Digestible nutrients.—The digestibility of grains displays some more or less substantial differences, which vary with the animals fed. Definite conclusions are unfortunately difficult to draw, because the several authorities differ to some extent on the digestion coefficients of individual components and the total. According to Morrison, the coefficients are highest for wheat (with the exception of that for the unimportant fat). Oats generally have the lowest digestion coefficients, though in palatability oats rank high as feed for most animals (see p. 55).

The total content of digestible nutrients of different grains depends not only on variations in the digestibility of individual nutrients (proteins, fats, nitrogen-free substances, and fibers) but even more on the varying proportions of nutrients with higher and lower digestion coefficients. Oats have both low digestion coefficients and a high content of the fiber with the lowest digestibility. They therefore rank lowest in content of total digestible nutrients. Barley, which ranks second in the fiber content, is for this reason next lowest in total digestible nutrients. Wheat and corn rank highest in this respect, while rye and grain sorghum fall slightly below.

Net energy value.—The net energy value of wheat is somewhat higher than that of corn, according to Morrison. Since the content of digestible nutrients in both is assumed to be similar, this should indicate that a larger amount of digestible nutrients of corn is spent for the digestion process than is the case with wheat; but such small differences as those displayed should be neglected owing to inaccuracies in the data.⁸

It may probably be taken for granted that in net energy

⁸ Kellner's starch equivalents, though supposed to yield results comparable to net energy value, are lower for wheat than for corn, partly owing to its lower "effectiveness-factor" (Table 2, footnote a). Differences in the prevailing types of grains may also be responsible for differences in the findings of Morrison and Kellner.

value corn and wheat exceed the other grains considered in this study. Rye, which is rather close to wheat and corn in total digestible nutrients, falls sensibly below in net energy value, according to Morrison, while Kellner puts rye equal to wheat. Grain sorghum is inferior to corn and wheat but superior to rye, according to Morrison. Barley is rather close to rye in net energy value, as it is also in total content of digestible nutrients. Oats occupy the lowest place. On these last two statements Kellner's data are in harmony with Morrison's.

FOOD USES

The principal uses of grain for human consumption are: (1) as porridge, (2) as flatbread, (3) as bread, and (4) as beverages.

Porridge.—Porridge, in the manifold forms found in the world,⁹ preceded the use of cereals in the form of bread.¹⁰ The ranks occupied by different grains in preference of consumers in the porridge era might have been quite different from those assigned nowadays. Rye—and perhaps also wheat, which makes a sticky and soggy porridge—may have ranked below buckwheat or oats.¹¹ With the development of the baking technique, human beings have shown their preference for consumption of grain in the form of baked bread, and por-

⁹ Porridge can be defined as a boiled preparation (usually on an open fire and more seldom in the oven) of cereals not raised by yeast or any other agent, which is more concentrated than a cereal soup but not concentrated enough to make the use of a knife preferable to that of a spoon. Strict borderlines between soup, porridge, and flatbread are impossible to draw. The same is true of flatbread and bread.

¹⁰ See the excellent study by Adam Maurizio, *Die Geschichte unserer Pflanzennahrung von den Urzeiten bis zur Gegenwart* (Berlin, 1927).

¹¹ Oatmeal porridge has always enjoyed a wide reputation as a palatable, nourishing, and very healthful food. J. R. Smith (*Industrial and Commercial Geography*, New York, 1913, p. 66) relates: "Dr. Johnson's famous English dictionary is said to have defined oats as 'food for men in Scotland, horses in England,' to which the Scotch replied, 'And England is noted for the excellence of her horses, Scotland for the excellence of her men.'" Some years ago the notion of the healthfulness of oatmeal porridge was challenged by the experiments of M. Mallanby, who inferred from them that oatmeal is very injurious to the teeth. Mallanby's findings are not regarded as conclusive, however. See E. V. McCollum and Nina Simmonds, *The Newer Knowledge of Nutrition* (3d ed., New York, 1925), pp. 485-88.

ridge has been relegated to the position of a supplementary food consumed along with bread. Outside of Asia and Africa, southeastern Europe (including parts of Italy) is the only region where porridge (*polenta* or *mammaliga*)¹² seems to have retained a large place in competition with bread.¹³ There it is the food primarily of the great masses of the rural population with low incomes, notably of the grain producers themselves. So far as means permit, it is readily abandoned, at least as a substitute for bread. Data supplied by the Rumanian Union of Agricultural Chambers indicate a large decline of the average consumption of *mammaliga* in the Old Kingdom since 1916.¹⁴ Hence we feel justified in considering the use of grains for bread as the higher ranking use, so far as Western civilization is concerned.¹⁵

Even as a supplementary food, porridge does not command as strong a position as bread. While the inroads of the potato merely curtailed bread consumption, the consumption of porridge has been almost discontinued in favor of the potato in several countries (Germany, for example). Also, with the recent shift to diversified food and especially to vegetables, bread consumption has not contracted to the same extent as the consumption of porridge. In this country, porridge has so declined in use that it is called a "breakfast food." Outside of Asia and Africa, where great masses of the population continue to live almost exclusively on cereals, Russia stands out as the only important country where porridges (in the form of *kasha*), prepared chiefly from buck-

¹² Polenta (in Italian) and *mammaliga* (in Rumanian) are preparations of corn meal resembling porridge. In some regions these seem to be the only form in which corn is eaten. In some others corn bread is baked as well, but on the whole the boiled preparations seem to predominate in the corn-consuming portions of Europe.

¹³ In Yugoslavia, for example, 2.3 million metric tons of corn were used for human consumption—most of it probably in the form of *mammaliga*—shortly before 1927, with total production being around 3 million tons. Otto v. Frankeš, *Die sozialökonomische Struktur der jugoslawischen Landwirtschaft* (Berlin, 1937), pp. 32-33.

¹⁴ League of Nations, *Nutrition, Final Report of the Mixed Committee of the League of Nations on the Relation of Nutrition to Health, Agriculture, and Economic Policy* (Geneva, 1937), p. 107.

¹⁵ Rice-eating Oriental nations, however, regard cooked rice as a food superior to the best bread.

wheat and millet, are consumed in large quantities.¹⁶ Even there the ratio between the amount of groats used for kasha and the amount of flour used for bread is only about 13 to 100. Consumers who can afford a more expensive diet reduce their bread consumption substantially, but they contract their consumption of kasha much more, frequently to the point of abandonment.

Maurizio¹⁷ defines alimentary pastes as a durable form of porridge, probably because they are boiled preparations of cereals. Alimentary pastes are produced in considerable amounts from grains other than wheat, but probably always only where the consumer cannot afford the wheaten product. They are widely used in Italy, and also over all of northern Africa according to Maurizio.¹⁸ Half of the wheat flour consumed in Japan is eaten in the form of alimentary pastes, as against only about 15 per cent in the form of bread.¹⁹ "Most of wheat flour, at least in North China, is consumed in the form of noodles."²⁰

Flatbread.—Historically, flatbread²¹ preceded bread in the narrow sense. Even flatbread has generally been preferred to boiled preparations of groats or flour. The development of the baking technique, which in its final stage implies raised bread, meant quite a revolution in human diet.

The introduction of flatbread brought about substantial

¹⁶ According to A. Lositsky, the per capita consumption of grains used for the preparation of porridge was equivalent to 57 pounds (rural population) and 33 pounds (urban population), on the average from 1923-24 to 1926-27. See his "Dynamics of Grain Consumption" in *Statistical Review*, 1927, No. 12, as quoted by V. P. Timoshenko, *Agricultural Russia and the Wheat Problem* (Food Research Institute, Grain Economics Series 1, Stanford University, Calif., 1932), p. 403.

¹⁷ Adam Maurizio, *Nahrungsmittel aus Getreide* (2d ed., Berlin, 1924), II, 148.

¹⁸ *Ibid.*, p. 145.

¹⁹ C. L. Alsberg, "Japanese Self-Sufficiency in Wheat," *Wheat Studies*, November 1935, XII, 79.

²⁰ Wilhelm Wagner, *Die Chinesische Landwirtschaft* (Berlin, 1926), p. 297.

²¹ Flatbread is a preparation of grains (usually ground or cracked) with water, not raised by yeast or other means, that is baked on an open fire or in the oven and is sufficiently solid to be cut with a knife. It includes similarly prepared products in the form of loaves rather than flat cakes, as well as similar preparations of cereals other than wheat and rye, even if baking powder or some other raising agent is used.

rearrangement in the ranking of the grains according to consumers' preferences. Wheat and rye possess advantages for use in baking, even if the property of the dough of wheat and rye flour to expand is not utilized fully by application of a raising agent. Though these advantages are much less in flatbread than in bread proper, flatbread from wheat seems to be preferred to all others the world over. There is apparently less agreement with regard to the ranking of the other grains in this use. Corn has to be accepted as a very appropriate material for flatbread.²² There seems to be little doubt that it should be ranked above all other grains except wheat and perhaps rye. Yet habit weighs heavily with foods. Mukerji writes: "Deo-dham sorghum, the cholam of southern India (*sorghum vulgare*) . . . yields the best grain, inferior only to the best wheat in bread-making."²³ The same writer says about corn:²⁴ "Bhutia ponnies and Sonthal coolies are able to digest maize even outside their own native climate. Maize contains more fat and is more fattening than other grains if it can be digested."²⁵

Flatbread is still in rather wide use over the world. Asia and Africa are its strongholds. Grains from which raised bread cannot be prepared (corn, barley, several kinds of millets, and buckwheat) are the principal materials. But large amounts of wheat also are used for the production of flatbread. Almost all wheat bread in British India is flatbread.²⁶ Wheaten flatbread is also widely consumed in some

²² The famous A. A. Parmentier, in *Le Maïs ou Blé de Turquie, apprécié sous tous ses rapports* (Paris, 1812), propagandized vigorously for the use of bread prepared from corn meal and potato starch in those sections of France (near Bordeaux) where people then ate mixed bread made of oats, barley, buckwheat, and screenings of wheat and rye (small and damaged grain left over in the process of cleaning). According to Parmentier, corn bread even with the admixture of potato starch would be far superior to the one described; "from flours well prepared, it is very agreeable to the eye and the palate"; "without being very light, it is perfectly raised" (*ibid.*, p. 260).

²³ N. G. Mukerji, *Handbook of Indian Agriculture* (3d ed., Calcutta, 1915), p. 196.
²⁴ *Ibid.*, p. 194.

²⁵ In the corn-producing areas of the Union of South Africa, the natives occupied on European plantations refuse corn and insist on getting sorghum grain for their daily food.

²⁶ Report on the Marketing of Wheat in India (Marketing Series No. 1, Delhi, 1937), pp. 71-72.

other Asiatic countries, such as Persia and Armenia,²⁷ and in northern Africa. But in Europe and America, the Jewish Easter bread (*matzoth*), a religious survival, is perhaps the most important representative of wheat flatbread, though some Mexican tortillas also are made of wheat.²⁸ Of flatbreads made from rye, only the *knäckebröd* of Sweden seems to be of importance as a supplement to raised bread.²⁹

The rapid decline in consumption of corn meal and corn flour in the southern United States, formerly a very important region of flatbread consumption,³⁰ and in some Danubian countries, indicates that flatbread cannot hold its position in competition with raised bread, wherever broad masses of consumers come in close touch with the latter and can afford to make the shift. Where wheat preparations have stopped at the flatbread stage, special reasons in fact can easily be discovered. Poor quality of the locally produced wheats, especially greater adaptation of natural conditions to durum wheat, extreme poverty and/or backwardness of the inhabitants, expensive fuel, and very high temperatures are—singly or in combination—among the most important reasons.³¹

Bread.—Bread in the narrow sense of the word is a baked product (mostly baked in the oven) made of a dough that has been raised by yeast or another agent. Some of the gases developed are retained in the dough. The pores containing the gases are hardened and made permanent by the heat. The

²⁷ Armenian flatbread has the form of very long towels which are hung over wooden poles in the bakery. Pieces of the weight required by customers are torn from them. A picture of the bakery and the bread is given in Adam Maurizio, *Die Getreidenahrung im Wandel der Zeiten* (Zurich, 1916), p. 105.

²⁸ Wheat cakes (pancakes, griddle cakes), widely consumed in the United States and some other countries, mostly are bread in the narrow sense or in any case not flatbread, since baking powder or yeast is commonly used in their preparation. The same is true of waffles.

²⁹ Families of city workers in 1932-33 consumed about 28 per cent of rye bread in the form of "hard rye bread," families belonging to the middle class about 38 per cent. *Statistisk Årsbok för Sverige*, 1935, p. 221.

³⁰ According to Holbrook Working, "The Decline in Per Capita Consumption of Flour in the United States," *Wheat Studies*, July 1926, II, 283, per capita consumption of corn meal in the United States in 1925 was less than one-quarter of that of 1890.

³¹ The same reasons by and large are responsible for the development and preservation of alimentary pastes as a staple food.

dough of only wheat and rye possesses the ability to retain gases; this is due to specific properties of the proteins contained in these grains.

Raised bread in the realm of Western civilization has long since attained a definite preference over cooked preparations of cereals and over flatbread, and for it wheat under all circumstances ranks above the other grains. Rye bread is preferred to flatbread from barley, oats, buckwheat, etc., especially in regions where corn is unknown. Heyne describes the food habits of the ancient Germans, at a time when the art of producing raised bread was already known, as follows: "The poorest bread is that made of oats, hence the food of the poor and of laborers. Barley bread does not achieve much more esteem. It also is peasants' food. Rye bread is appraised higher."³² The same attitude existed in Great Britain. In 1586 Harrison observed:³³

. . . . the price of corne of late years has been so high that the artificer and poore labouring man is not able to reach unto it, but is driven to content himselfe with horse-corne, I meane, beanes, peason, otes, tares, and lintels; and therefore it is a true proverbe and never so well verified as now, that hunger setteth his first foot into the horse manger. If the world last a while after this rate, wheate and rie will be no graine for poore men to feed on, and some caterpillers there are that can saie so much alreadie.

The other grains, and even such products as peas, beans, and vetches, continued to be used in breadmaking for centuries because the supplies of wheat and rye were largely insufficient.³⁴ The use of ill-suited materials was to some small extent alleviated by the addition of some suitable material, mostly rye. It is seldom realized how recently, even in the most advanced countries, the use of inappropriate

³² Moriz Heyne, *Fünf Bücher deutscher Hausaltertümer von den ältesten geschichtlichen Zeiten bis zum 16. Jahrhundert. Das deutsche Nahrungswesen* (Leipzig, 1901), II, 270-71.

³³ Quoted in John Percival, *Wheat in Great Britain* (Leighton, Shinfield, Reading, Berks, Eng., 1934), p. 17.

³⁴ See, for example, Sir William Ashley, *The Bread of Our Forefathers* (Oxford, Eng., 1928), for information on Great Britain; or Heyne, *op. cit.*, for information on the ancient Germans.

materials in breadmaking has been discontinued entirely. As late as 1764 in England and Wales, according to Charles Smith, more than 12 per cent of the grain used for bread was barley, more than 10 per cent was oats, and the proportions were much higher in certain regions of the country.³⁵

Wheat bread versus rye bread.—Wheat and rye as materials for bread probably never formed a common front against the other grains. The position of wheat was so superior that it did not condescend to take an ally. It fought not only the grains and other products from which raised bread cannot be made at all (except in admixtures), but also rye, which displays inferior leavening properties and other substantial shortcomings as a material for breadmaking.

First, there is a purely quantitative factor. The trend of breadmaking has definitely been toward exclusive use of the inner portion of the grain kernel, i.e., of flour of white or grayish-white color and reasonably free of fiber. Owing to differences in the shape of the wheat and rye kernels, and to the thicker skin of the rye kernel, a higher percentage of white flour can be extracted from wheat than from rye. If the extraction of good grade wheat flour is set at 70 per cent, the extraction of comparable rye flour is hardly higher than 60 per cent. At these extractions and with flour twice as valuable as bran, even with equal prices of wheat and rye flour the price of wheat must be about 7 per cent higher than that of rye.

Yet differences in the quality of wheat and rye bread play a considerably greater role in the discrimination against rye than differences in the extraction of flour. Bread made of rye has a much smaller volume than bread made of wheat. The proteins of wheat in the main consist of a mixture of two colloidal substances, gliadin and glutenin (the proteins of white wheat flour consist almost exclusively of them). Gliadin pos-

³⁵ Ashley, *op. cit.*, pp. 5-8, 24. Smith's statement referred to the proportions of barley and oats used in the preparation of bread. Ashley infers, however, that the proportion of those who ate bread made with barley or oats, unmixed or mixed with a more appropriate grain, was larger than was indicated by the percentages computed, for part of the barley and oats was mixed with other grains.

sesses the property of stretching almost indefinitely. Glutenin, on the other hand, is a rather tough substance. Gliadin and glutenin together yield the gluten, an elastic substance that possesses the property of stretching and then contracting to its former volume after the power applied is removed.³⁶ Some students even believe that the quality of bread depends on the right ratio between the content of gliadin and glutenin.³⁷ An excess of gliadin is supposed to produce a soft gluten that stretches too much but is not sufficiently elastic. An excessive proportion of glutenin results in a gluten too tough but also insufficiently elastic. In both cases, a loaf of small volume and poor texture is the consequence.³⁸

Rye contains only one of the two proteins essential for breadmaking, the soft gliadin. Consequently the dough made of rye flour retains a much smaller quantity of the gases than the dough made of wheat. According to Maurizio,³⁹ the pores represent the following percentages of the total bread volume:

Whole-rye bread	28.5 to 49.2
Rye bread	55.7 to 70.7
Whole-wheat bread	64.3
Wheat bread	73.0 to 83.0

³⁶ In all cases sufficient moistening is assumed.

³⁷ The idea dates from the end of the last century, and was fathered by Aimé Girard. See Adam Maurizio, *Nahrungsmittel aus Getreide*, I, 400.

³⁸ In support of the idea that an excessive proportion of gliadin is accompanied by low bread volume, Harry Snyder (*Bread*, New York, 1930, p. 242) brings the following data in which the composition of the gluten of hard wheats producing bread of large volume and fine texture is compared with that of soft wheats displaying the opposite properties:

Variety	Gluten as percentage of flour	Percentage of gluten	
		Gliadin	Glutenin
Hard wheat			
Scotch Fife	12.46	58.3	41.7
Wellman's Fife	10.18	60.3	39.7
Winter	10.16	54.6	45.4
Soft wheat			
Winter	9.23	70.8	29.2
Blue Stem	11.75	66.7	33.3
Calcutta	6.70	73.1	26.9

For a divergent opinion see C. H. Bailey, *The Chemistry of Wheat Flour* (New York, 1925), pp. 263-65.

³⁹ *Nahrungsmittel aus Getreide*, I, 360.

Rye bread, moreover, does not have as fine a texture as wheat bread.⁴⁰ Since volume and fine texture of bread enhance digestibility, this fact tend to make rye bread inferior to wheat bread in this regard. But wheat bread surpasses rye bread in digestibility even without reference to difference in the volume and texture of the bread. According to Hindhede, a well-known Danish dietitian, the loss in the digestive process is equivalent to the percentages shown below:⁴¹

Type	Total	Nitrogen substances	Fat	Minerals	Carbohy- drates
Whole-rye bread ..	13.1	34.7	9.3	49.8	9.6
Whole-wheat bread	8.4	15.7	5.9	37.9	6.6

The difference in digestibility, especially with regard to nitrogen substances, is very substantial.

The large difference between the content of digestible nutrients and the net energy value in rye (Table 1, p. 30) indicates a considerable loss of digestible nutrients in the digestive process of animals. The same is still more true of man, owing to the materially lesser efficiency of the human digestive system. The German says "*Roggenbrot hält länger vor*," meaning that rye bread keeps one longer satiated. (This and the other statements seem to pertain not only to whole-rye bread but to rye bread from flour of low extraction as well.) The observed fact that rye bread keeps people warmer than wheat bread can be explained only by the larger production of heat in the prolonged digestive process. Longer digestion and more heat developed mean a considerable expenditure of digestible nutrients for the digestive process. The lesser digestibility of rye bread also is the reason for the common observation that rye bread requires more chewing.

Thus the proportion of both indigestible substances and

⁴⁰ The same volume may be occupied by relatively few large pores (poor texture), or a huge number of small pores (fine texture).

⁴¹ Quoted from M. P. Neumann, *op. cit.* (under Table 3), p. 456. It is unfortunately not stated positively whether the percentages refer to substances undigested or include also the expenditure of nutrients in the digestive process. The first seems the more likely.

digestible substances used in the digestive process must be materially higher in rye bread than in wheat bread made of flour of corresponding extraction rates. Rye bread also tends to produce gases. It possesses a strong taste which many like, particularly when small quantities are consumed. The overwhelming majority of consumers, however, object to this taste, especially when the consumption of rye bread is large.⁴² Where large amounts of rye bread are consumed, the principal reason is cheapness rather than liking.

Whoever attempts to appraise the competition between wheat and rye bread from observation of the situation in the United States is easily misled. Here the competition is based entirely on preference. The consumer, when asking for rye bread, is charged at least as much per pound as for wheat bread, and sometimes more. Such a price ratio between wheat and rye bread, however, is quite exceptional. Moreover, the situation in this country is inappropriate for generalizations regarding competition between rye and wheat bread, since practically no rye bread is produced. What is sold as rye bread is actually rye-flavored wheat bread. From 1923 to 1931, federal bread standards required that the flour from which rye bread is made should contain at least a third of rye flour;⁴³ but when revised definitions were proposed in 1931, the trade objected and the definition of rye bread was deleted.⁴⁴ Much "rye bread" indeed is made with an even smaller content of rye flour. Negligible quantities of bread made entirely or primarily of rye flour are sold in the East under the designation "pumpernickel."⁴⁵ In the West, pumpernickel is made of a mixture in which wheat flour mostly predominates;

⁴² The preference as to the taste of the every-day and all-day cereal seems generally to be toward milder taste or tastelessness. It hardly is a mere chance that rice, the only grain which along with wheat has been able to preserve a predominant position as the major source of carbohydrates for men based on preference, has a mild taste or is even described as tasteless.

⁴³ *Almanack and Year Book of the Breadstuffs Industries* (Northwestern Miller, Apr. 2, 1930), p. 3.

⁴⁴ *Ibid.*, Apr. 1, 1931, p. 3, and Apr. 13, 1932, p. 9; *Northwestern Miller*, Nov. 11, 1931, p. 363.

⁴⁵ This should not be confused with the German product of the same name, which is similar only in that both are prepared from dark rye flour.

and on the Pacific Coast, some contains hardly as much as one-third of rye. Furthermore, while rye bread in Europe is prepared by a long process of developing a "sour" dough left over from the preceding baking, in this country "rye bread" (including pumpernickel) is almost exclusively prepared with yeast by practically the same short process used in the preparation of wheat bread.⁴⁶

As in the United States, there are undoubtedly in Europe some consumers who prefer to have a portion, but seldom all, of their bread in the form of rye bread, to such an extent that they would continue to buy it even at equal prices of wheat and rye bread.⁴⁷ Probably these consumers are only a small minority; in any case, the amount of rye required to satisfy their requirements is small. In the United States, where consumers have to pay for rye bread as much as for wheat bread, or more, rye flour makes up only about 1.5 per cent of the flour utilized in breadmaking, though the amount of "rye bread" may amount to as much as 4.5-5.0 per cent. For the majority of its users even such rye-flavored wheat bread is only one of many special breads which are used for a change.

In countries where much rye bread is consumed, it is substantially cheaper than wheat bread. There, wheat bread is consumed mainly in very small rolls and, since wrapping is not practiced, wheat bread is desired extremely fresh. Rye bread, on the other hand, is usually baked in loaves of several pounds. This saves labor. Not infrequently the prevailing type of rye bread is that in which the loaves stick one to another. This saves space and fuel. Rye bread prepared by the "sour" process does not become stale as quickly as wheat bread and, indeed, is seldom consumed fresh. This permits more efficient utilization of plant and labor. Rye bread retains more water than comparable types of wheat bread. As a result,

⁴⁶ A. E. Taylor writes, "Our rye breads incline to be imitations of American wheat breads rather than imitations of European rye breads." See "Rye in Its Relations to Wheat," *Wheat Studies*, March 1928, IV, 207.

⁴⁷ The bulk of the consumers of "rye bread" in the United States probably consists of such persons who immigrated to this country, and their descendants. The habit is mostly lost in a generation or two.

the difference in price between rye and wheat bread is larger—usually much larger—than that between wheat and rye flour. Rye bread is commonly much cheaper than wheat bread even if rye bread is made of a flour of lower extraction than that used for wheat bread. The price of wheaten rolls per pound in Berlin at the end of 1937 was exactly twice as high as that of rye bread in loaves of approximately three pounds, and this was a normal price ratio. In Latvia, on the average of 1930–34, wheat bread was 135 per cent more expensive than rye bread.⁴⁸ On the average in 1932–36 in Austria, small rolls⁴⁹ were more expensive by 175 per cent than the so-called “Brot” which was baked in loaves from a blend of 75 per cent rye flour and 25 per cent wheat flour.⁵⁰

There are of course large differences in the degree of resistance of consumers to rye bread. A Sicilian would probably go barefoot rather than do without wheat bread. By contrast, many persons in northern Germany would not give up one of their luxurious habits for the sake of having wheat bread rather than rye bread with their supper sandwiches; but they insist on wheat bread with their morning coffee and on wheat cookies or cake with their afternoon coffee. With money considerations entirely dismissed, consumers even in the present strongholds of rye consumption, or at least their successors, would probably show preference for wheat bread.⁵¹

The definite preference for wheat bread is clearly revealed

⁴⁸ League of Nations. *The Problem of Nutrition. Vol. III. Nutrition in Various Countries* (Geneva, 1936), p. 55.

⁴⁹ These small rolls (10.8 to the pound) were the only form in which wheat bread was obtainable.

⁵⁰ A. Kodlik, “The Spread between Producers’ and Consumers’ Prices of Certain Foodstuffs in Austria,” *International Review of Agriculture*, June 1937, XXVIII, 184–85.

⁵¹ The considerable amount of heat developed in the act of digesting rye bread is probably at least one of the reasons why the objection to rye bread in the Northern Hemisphere increases from north to south. The better matching of rye with some other foods (strongly salted butter, sharp-tasting cheeses and sausages, beer, and the like) is brought forward as a further reason for explaining strong adherence to rye bread in some countries. The common habit of toasting bread, on the other hand, is stressed as a reason why rye bread (which toasts poorly) is little used in this country. All such reasons can claim only minor importance. Some of the types of food mentioned are found in countries not using rye bread. Moreover, most such foods are giving way to finer foods.

by the history of bread consumption in Europe. Two centuries ago, and even a few decades ago, rye bread was in much wider use and its position in the countries which adhere to it was much stronger than now. In 1764 rye was as important as wheat in northern England, while in Wales it was four times as important.⁵² The change to wheat as the chief or only bread grain had become complete throughout Great Britain about 1825 or earlier,⁵³ and no traces of rye bread can be found there in recent decades.

The "égalité" which was sought by the great French Revolution was also "l'égalité" in bread. Before, white wheat bread was the bread of the rich; the revolution made it the bread of everybody. Moving east, wheat bread expelled rye bread from Belgium also. Almost all the rye grown in the Netherlands is used as feed. A further step, and western Germany was invaded. Coming from the south, wheat entirely conquered Switzerland and occupied a stronghold in southern Germany. The same movement of wheat from south to north can be observed farther east, even in Russia.

Nowadays, heavy consumption of rye bread has become confined to a relatively limited region, comprising large parts of Germany, Czechoslovakia, Austria, the Scandinavian and Baltic states, Poland, and central and northern Russia. Even there, the position of rye as a foodstuff is by no means strong. The per capita consumption is declining, the admixture of wheat flour to rye bread increases, and the use of pure rye bread is more and more confined to the poorer population. In Sweden, for example, rye bread contained from 50 to 55 per cent of wheat flour a few years ago, when Shollenberger visited it.⁵⁴ Particularly striking in recent years has been the development in Russia. The area in wheat increased in the past decade by almost 35 per cent, while the rye acreage declined by more than 10 per cent. Nevertheless, very small

⁵² Ashley, *op. cit.*, p. 7.

⁵³ Percival, *op. cit.*, p. 18.

⁵⁴ J. H. Shollenberger, *Wheat Requirements in Europe* (U.S. Dept. Agr. Tech. Bull. 535, September 1936), p. 162.

surpluses of wheat were available for export except in years of high yields.

The consumption of wheat is to a very large extent independent of local production. The number of regions which rely on imports for all, or most, of their wheat is too large to be easily enumerated. Consumption of rye (and corn), however, is firmly bound to the place where it is grown. The regions where rye still plays an important role as a foodstuff are those where enough wheat to satisfy the needs cannot be produced at all or can be produced only at a very high cost. A glance at a map of soils shows that poor cut-over lands, some of them of very light type, are typical of rye-eating regions, and their climates also are mostly too severe for the higher-yielding winter wheat.⁵⁵ Inter-regional trade in rye is limited primarily to covering small deficits of regions which are themselves heavy producers of rye, these deficits frequently being caused by year-to-year variations in crops. Norway is the only country that imports considerable amounts of rye while producing little, but Norway was long united with rye-producing Sweden.

Even the intra-regional trade in rye is incomparably more limited than that of wheat. Some explanation for this phenomenon can be found in the fact that the objectionable properties of rye bread are felt less strongly in the country, with its harder physical work and ample outdoor life, than in the cities with their primarily indoor occupations. But the larger purchasing power of the city population is even more important. Finally, there is the fact that when the producer eats bread made of his own rye rather than of wheat brought from other regions he saves more than a city dweller can save by eating rye instead of wheat bread. The protection of the rather high marketing costs more and more becomes the last

⁵⁵ Not all regions with "rye" soil and corresponding climate are producers and consumers of rye. A further requirement is that the population be of moderate means so that buying wheat elsewhere would involve quite a financial strain. But the tendency of poor natural conditions to make poor the population inhabiting it, very strong in the past, still preserves considerable effectiveness.

refuge of rye (and corn) in their fight against wheat for a portion of the demand for food uses.⁵⁶

Propaganda against nonprotective foods enters into the competition between wheat and rye bread. As stated, there has long been a tendency to use only the inner portion of the wheat and rye kernel for the preparation of flour and bread. Almost exclusively partaken in this form, wheat is deprived of most of the mineral matter and fat, of a substantial portion of proteins, and, most important, of all the vitamins. Strong objections were raised to this form of use long before the great significance of vitamins for human life had been recognized. The objections to the so-called nonprotective foods—those that do not contain vitamins and have to be supplemented by other foods particularly rich in them⁵⁷—has since grown stronger. Recently the campaign against the nonprotective foods has been given official support by a League of Nations Committee.⁵⁸ Its Technical Commission stated:

White flour in the process of milling is deprived of important nutritive elements. Its use should be decreased and partial substitution of lightly milled cereals, and especially potatoes, is recommended.

. . . bread should be made more protective by restoring to the flour, as far as possible, the special nutritive principles contained in the husk and germ of the grain, particularly of the vitamin B group.

This is not the place to analyze at length the pro's and con's of consumption of products made of the inner portions of

⁵⁶ For particulars on the competition between wheat and rye in Germany, see N. Jasny, "Wheat Problems and Policies in Germany," *Wheat Studies*, November 1936, XIII, 101-10, and *passim*.

M. K. Bennett, who has carefully studied the statistics of bread consumption in many European countries ("Per Capita Wheat Consumption in Western Europe," *Wheat Studies*, March 1935, XI, 255-305), is somewhat more cautious in interpreting the available data and assigns more weight to preference for rye bread, a minor factor in the long run in the opinion of the writer. Bennett's opinion is that the absence of rye bread from Holland and Switzerland, and its presence in substantial amount in Denmark and Sweden, cannot be explained either by differences in incomes or by "heating" qualities of rye in the digestive process, and must therefore be explained in terms of preference.

⁵⁷ The expressions "protective" and "nonprotective" foods were coined by E. V. McCollum. Sugar and vegetable oils are the other principal nonprotective foods.

⁵⁸ *Nutrition. Final Report of the Mixed Committee of the League of Nations on the Relation of Nutrition to Health, Agriculture, and Economic Policy*, p. 92.

the grain kernels.⁵⁹ The use of the whole kernel involves the introduction in the digestive organs of considerable amounts of indigestible substances, with a tendency to develop much gas in the digestive system. When the diet consists mostly of cereals and the cereals are eaten with all of their outer cover, this may be definitely undesirable. It may not do harm, or may even be desirable, if the total consumption of cereals is small; but under these circumstances other foods consumed are likely to contain the necessary amount of vitamins. If they do not, propaganda in favor of such a balanced diet seems to be more promising than publicity against nonprotective foods.⁶⁰

At all events, the propaganda against flour of short extraction seems not to have sensibly affected the drift from the use of flour of long extraction. There have appeared in the market, it is true, products which are said to contain some of the desirable ingredients of the outer portions of the kernels without the undesirable fiber and pentosans. Conceivably these or equivalent desirable ingredients could be provided more cheaply in another way. After all, so long as meat, bacon, eggs, butter, and milk (milk is in the greatest favor with dietitians) are wanted, animals have to be fed, and there is not much reason to produce for them some other feed while the extremely useful millfeed (one of the best feeds for milch cows) is almost wasted in the human intestinal tract.

If propaganda against the nonprotective foods should succeed, the effect in countries where wheat has displaced all other grains as material for bread would probably be merely that wheaten flour of higher extraction would be used in breadmaking. With no change in the amounts of bread consumption, this would involve contraction of the wheat require-

⁵⁹ Cf. A. E. Taylor, "The Place of Wheat in the Diet," *Wheat Studies*, February 1929, V, 147-74.

⁶⁰ McCollum and Simmonds write (*op. cit.*, p. 132): "As a rule those who advocate this practice [turning from white wheat flour to whole wheat flour] exhibit in some degree the spectral mien of the dyspeptic. They would gain much more through adhering to a diet well balanced than through adopting this or any other dietary fad."

ments in a somewhat larger proportion than the increase in the average extraction.⁶¹ Other grains are unlikely to make inroads into the position occupied by wheat.

One cannot be so positive with regard to the competitive position of the other grains with wheat in case the propaganda against nonprotective foods should be crowned with success in countries where much rye bread is consumed. In some of them, a large difference in the extraction of the flours from which the common wheat and rye breads are prepared can be observed. While wheat bread everywhere is made almost exclusively of white flour,⁶² much rye flour which contains part or all of the outer cover is used to make bread. The transition from rye to wheat, therefore, is frequently a direct jump from coarse black or gray bread made of rye or a mixture of flours to white bread made of wheat. The abolition of white wheat bread would make the difference between wheaten and other breads less striking and might retard the transition from rye to wheat. The shift may be hampered even where rye bread also is made of flour entirely or practically free from bran. The difference in attractiveness between whole-wheat bread and whole-rye bread may be found to be less than between wheat and rye bread when both are made of flour without bran.

BEVERAGE USES

Liquors can be prepared in such a way that their taste and aroma strongly reflect the material of which they are made. Moreover, the price of the raw material of which the heavily taxed liquors are made may constitute as little as 2 per cent of their retail price or less. Under these conditions, the demand for liquors of the type described may result in great inelasticity of the demand for specific raw materials. This seems actually to be the case with regard to the demand, for

⁶¹ The water-absorption of flours of long extraction is larger than that of flours of low extraction.

⁶² The habit of preparing wheat bread of a flour free from bran seems to be centuries old. Heyne, *op. cit.*, p. 271.

example, for rye for rye whisky in the United States and Canada, for corn for bourbon whisky in the United States, and for barley in Great Britain. The demand for these whiskies and their materials depends strongly on the variations in the purchasing power of the population, but little on prices of different raw materials and the relationship between them.⁶⁸

But many liquors are prepared either of any alcohol or of alcohol with a broader selection of raw materials, such as grain alcohol. In many countries, such as Russia, Poland, Germany, and Austria, the consumption of liquors of specific types is negligible, and alcohol from any source is the standard material of which different liquors are prepared. The Russian *vodka* is simply a neutral spirit diluted with water, while good *vodka* is diluted grain alcohol. Gin is prepared of any neutral spirit. The same is true of practically all technical uses of alcohol.

The raw material used in the preparation of neutral spirits is naturally that which costs least per unit of starch, with the value of by-products considered. The situation is the same with regard to the production of starch (except for some specific starches for which white corn or rice are preferred), syrup, etc., whether these products are destined for human food or for other uses. The use for the preparation of neutral spirits, starch, syrup, and the like, is therefore the lowest ranking one for each kind of grain. The ranks of the individual grains in these uses are determined primarily by their starch content, corn and wheat ranking highest and oats lowest. The high oil content in the easily separated germ of corn imparts an additional value to this grain as raw material for the preparation of alcohol, starch, syrup, and similar products.

Only barley possesses the specific properties needed in the preparation of beer. Moreover, barley used in beer production is a rather delicate product, much more carefully

⁶⁸ There seem to exist slight possibilities of adjustments by increasing the stocks of spirits in years of cheap raw materials and by changes in the composition of blended whiskies.

selected than grain used for any other purpose, even for the production of the finest wheat flours. Barleys used in the preparation of beer ought to be sound and thoroughly ripe, and to consist of kernels of approximately equal size (in order to insure practically complete and even germination), and plump and thin-skinned (to yield a high percentage of extract).⁶⁴ Finally, good malting barleys should not have a high content of protein because beer made of such barley will not be clear.

Only two-row barleys of good quality, with a low or moderately low content of protein, meet all these requirements. In Europe no other barleys are in general used in beer preparation. The only important exception known to the writer is the mixture in Great Britain of the domestic two-row barleys with a certain percentage of six-row barleys raised under dry conditions with a great deal of sunshine (the so-called sunshine barleys), in order to offset the extremely low diastatic power of the barleys grown in that foggy country. Californian barley of high quality is the type mostly used for this purpose. In the United States, however, six-row barleys constitute the principal or exclusive raw material used by brewers;⁶⁵ their use is made possible by reducing the excessive content of protein by addition of starch. Otherwise the requirements for good malting barley are very strong here also. Some types of beer require special barleys.

The large effect of the character and quality of the barley on the character and quality of the beer leads to large premiums for suitable qualities. Even a high-priced barley constitutes only a small portion of the price of beer, particularly because there is hardly a country in which beer is not taxed rather heavily. The premiums paid for desirable qualities of malting barley are several times as large as those observed in all grains other than oats, the grain with the largest differences in the content of nutrients (see pp. 128-32).

⁶⁴ But naked barley is unusable in beer preparation.

⁶⁵ Whether such substitution of six-row barleys involves some sacrifice in quality of the beer is beyond the knowledge of the writer.

FEED USES

All kinds of grains are valuable feeds, though important variations are caused by the differences in the properties of the grains and in the requirements of different kinds of livestock. In view of the immense numbers of livestock fed day in and day out, and the still larger amounts of feed used for this purpose, it may be surprising that the appraisal of the suitability of different grains to different requirements meets with substantial difficulties. Even in a single region, ideas about the proper feed for specific conditions do not coincide, and opinions held in different countries frequently diverge widely.

The divergences in opinions are largest among feeders. The writer has heard farmers say that "barley is no good for hogs," that "hogs do not thrive on sorghum," and (outside the United States) that "corn is not a hog feed." Yet even the opinions of experts, although not diverging as much as those of farmers and business men, in some pertinent points lack unanimity to such an extent as to make conclusions difficult.⁶⁶

Corn is an all-round readily digestible feed with a high content of nutrients. According to Morrison,⁶⁷ it is probably the most palatable of the cereals to farm animals. Wheat contains as much digestible nutrients as corn (Tables 1 and 2, pp. 30 and 31) and its content of proteins is higher than that of corn, but wheat can be fed heavily with less confidence. "Care has to be taken when feeding wheat to livestock or digestive trouble may result."⁶⁸ The defects of wheat as a

⁶⁶ Both in the United States and Europe, research workers are attempting to ascertain to what extent pork and bacon from hogs fed corn are inferior to pork and bacon from hogs fed barley (see pp. 60-63). Yet in South Dakota the prejudice against barley as a hog feed was apparently so strong that it was found advisable to spend money for experiments showing that "pigs fattened on ground barley . . . produced as good carcasses as pigs fattened on shelled corn . . ." J. W. Wilson and Turner Wright, *Barley as a Fattening Feed for Cattle and Swine in South Dakota* (South Dakota Agr. Exp. Sta. Bull. 262, April 1931), p. 38.

⁶⁷ F. B. Morrison, *op. cit.* (under Table 1), p. 329.

⁶⁸ A. S. Carlos, *Feeding Stuffs* (London, 1928), p. 14.

feed apparently have their origin in its capacity when moistened to form gluten—the same property that makes it so desirable for bread preparation; “dough balls” that resist digestion are readily formed. Digestive troubles are particularly likely to occur if high-protein wheats, the most valuable for breadmaking, are fed, especially the low grades of these wheats which contain even more protein than the higher grades.⁶⁹

Barley, which contains about 5 per cent less digestible nutrients than corn, is likewise a highly digestible feed. It possesses good fattening properties, but these are supposed to make it less desirable for use with working animals. Oats contain about 15 per cent less digestible nutrients than corn. In spite of the high content of the rather indigestible fiber, oats are considered very good feed. According to Kellner, oats excel all other grains in palatability and healthfulness.⁷⁰ In the common opinion, oats are the best grain for horses. Some oats in the ration also are considered useful for all kinds of livestock except hogs in the fattening stage: oats are assumed to be particularly valuable for cows in calf, calves, horses in colt, sows in pig, sick livestock, and other animals that require careful treatment.

Rye as a feedstuff ranks last. Germany has probably had the greatest experience in feeding rye, since at least a quarter of the large German rye production is used for feed. Kellner, the foremost authority on feeds and feeding in Europe, writes:

Rye has the reputation to stimulate the exertion of power rather than the increase in weight, but readily to bring about digestive troubles and— . . . particularly when freshly harvested—to be the most dangerous among the cereals. It is always fed only in small quantities, cooked but not ground.⁷¹

⁶⁹ E. W. Crampton, *The Comparative Feeding Values for Livestock of Barley, Oats, Wheat, Rye and Corn* (Canadian National Research Council, Report 28, 1933), p. 55.

⁷⁰ O. J. Kellner, *Grundzüge der Fütterungslehre* (8th ed., Berlin, 1929), p. 102.

⁷¹ *Ibid.*, p. 103. A similar statement is found in H. E. Woodman, *Home-Grown Feeding Stuffs* (Great Britain Ministry of Agriculture and Fisheries Bull. 13, 1933), p. 11, but it may have been made on the authority of Kellner. Kellner's statement on cooking rye is probably to be regarded as a strong recommendation rather than a statement of what is actually done.

Feeding horses.—It seems to be the unanimous opinion of feeding experts, armies, and horse owners in general that oats are the best feed for horses, and horses the world over also seem to prefer oats.⁷² The superiority of oats is particularly large where prolonged, speedy work is required of horses. The divergences of opinion emerge when it comes to substitutes for oats in horse feeding and to the appraisal of the unfavorable consequences, if any, these substitutes may cause.

Feeders of horses in the United States have had the greatest experience with corn, and no unfavorable results from the substitution of corn for oats have been noticed. Moreover, according to Morrison,⁷³ a mixture of oats with more concentrated grains (corn, ground barley) is more desirable for horses at very hard work than oats alone. In Europe (except probably in certain portions of southern Europe), however, the possibility of substituting corn for oats is acknowledged much more reluctantly. Kellner, besides stating that oats exceed all other grains in healthfulness and palatability, says that oats “. . . are in such a high esteem as concentrates for the most sensitive of all animals, the horse, that only reluctantly, and then only in part, are they replaced by other feeds.”⁷⁴ While according to Morrison, half corn and half oats increases the efficiency of horses at heavy work, Kellner merely says: “Up to half of the grain ration of horses can consist of corn, without diminishing their efficiency or other negative consequences.”⁷⁵

Watson and More⁷⁶ write: “If corn is to form a large part of the ration [of horses], it must be introduced gradually, and it gives the best results when mixed with oats and dry

⁷² It is something of an advantage of oats as a horse feed that only small losses are involved when whole oats are fed. This saves the cost of grinding. If whole corn is fed, the losses are larger than in the case of oats, and corn is therefore mostly fed crushed. Wheat, barley, and rye have to be fed in crushed or coarsely ground form.

⁷³ F. B. Morrison, *op. cit.*, p. 446.

⁷⁴ O. J. Kellner, *Grundzüge der Fütterungslehre*, p. 102.

⁷⁵ *Ibid.*

⁷⁶ J. A. S. Watson and J. A. More, *Agriculture; The Science and Practice of British Farming* (2d ed., Edinburgh, 1928), p. 573.

bran in order to lighten it." The rations recommended by these authors for light and medium work do not contain any corn, but the daily ration for heavy work consists of 10 pounds of corn, 5 pounds of oats, 5 pounds of bran, and 14 pounds of hay. A bulletin published by the Ministry of Agriculture and Fisheries of Great Britain says:⁷⁷

Although oats are generally accepted as the best food for horses, it is possible to effect very great economy by replacing part of the oats by feeding stuffs which supply what may be called "oat equivalent" at a much cheaper rate The prejudice against maize for horses is due chiefly to the fact that most horse-keepers replace oats by maize pound for pound. If only 7.3 lb. of maize is given in place of 10 lb. of oats good results are obtained, especially with horses doing slow work.

The most pessimistic is the opinion of Mukerji, reflecting the attitude in British India:⁷⁸ "Maize diet gives the tendency to accumulate internal fat which is injurious to working animals like bullocks and horses." He adds, "But climate and habit have a great deal to do with the question of diet."

Where oats are extensively grown, barley mostly is supposed to be an inferior feed for horses. Kellner writes that barley "as horse feed is liable to bring about an increase in body-weight, does not stimulate the energy and endurance as well and also is not as palatable as oats."⁷⁹ But Watson and More⁸⁰ describe barley as a "good horse corn." Hansson, the renowned Swedish expert, also does not feel it necessary to include a warning against barley as a horse feed.⁸¹ Barley is widely used for horse feed in the Pacific Coast states, southern Europe, parts of Asia, and many other places, evidently without important drawbacks. The famous horses of Arabia are fed barley.

Wheat for horses seems to meet with much greater objections than barley. Crampton summarizes the findings of a

⁷⁷ T. B. Wood, *Rations for Live Stock*, revised by H. E. Woodman (Great Britain Ministry of Agriculture and Fisheries Bull. 48, 1936), p. 40.

⁷⁸ N. G. Mukerji, *op. cit.*, pp. 193-94.

⁷⁹ *Die Ernährung der landwirtschaftlichen Nutztiere*, p. 355.

⁸⁰ J. A. S. Watson and J. A. More, *loc. cit.*

⁸¹ Nils Hansson, *Fütterung der Haustiere. Ihre theoretischen Grundlagen und ihre wirtschaftliche Durchführung* (2d ed., Dresden and Leipzig, 1929).

considerable number of studies: "Barley is preferable to wheat as a horse feed because of digestive disorders encountered when wheat is fed."⁸² Watson and More believe wheat an unsatisfactory feed for horses, since it is "liable to produce colic unless fed with care."⁸³ "Rye is worse," in their opinion, for this purpose. Kellner probably somewhat stretches the adaptability of rye for horse feeding, when he says that this grain "can constitute up to at most half of the grain ration."⁸⁴

Thus, in spite of the very strong objection of many horse owners to the use of any grain other than oats for their horses, and their preparedness to pay for oats as horse feed considerably more than is justified by their low content of nutrients, the possibility of adequate substitution for oats as a horse feed—except perhaps for very speedy action—must be accepted as beyond any doubt. Corn is an almost perfect substitute, especially in combination with wheaten bran. Barley comes next. Wheat and rye, it is true, are considerably less desirable, especially if they constitute a large proportion of the grain ration.

Feeding hogs.—Corn commands a high standing in the United States as a hog feed. According to Morrison,⁸⁵

Corn is unsurpassed as a feed for growing and fattening pigs and therefore is commonly taken as the standard with which other grains are compared. It is also entirely satisfactory for brood sows and other breeding stock when its deficiencies in protein, minerals, and vitamins are corrected, and when the amount of this concentrated grain is so limited that such swine do not become too fat.

Barley also is an excellent feed for hogs; but hogs prefer corn,⁸⁶ and barley is somewhat less concentrated than corn.

⁸² E. W. Crampton, *op. cit.*, p. 13. The conclusion of the same study with regard to "barley versus oats for horses" (p. 12) is, "Barley is a somewhat more nutritious feed than oats, but may be unpalatable to horses."

⁸³ J. A. S. Watson and J. A. More, *loc. cit.*

⁸⁴ O. J. Kellner, *Grundzüge der Fütterungslehre*, p. 103.

⁸⁵ F. B. Morrison, *op. cit.*, p. 851.

⁸⁶ According to experiments in North Dakota, hogs used to corn are reluctant to eat barley. The trouble does not arise with hogs raised on barley. See J. H. Shepperd, *The Northern Pig, Its Habits, Breeding, and Management* (North Dakota Agr. Exp. Sta. Bull. 230, July 1929), pp. 95-96.

Experiments cited by Morrison indicate that 83 to 87 pounds of corn produce as much pork as 100 pounds of barley. Corn requires, however, the addition of more protein concentrates than barley; in the experiments just cited, the difference was 2 to 4 pounds of supplements. With the price differences between grain and supplements considered, 100 pounds of barley were worth as much as 91 to 93 pounds of corn.⁸⁶

Oats are considered to contain too much fiber to be a proper feed for hogs with their short alimentary canal. Kellner⁸⁷ approves of oats for pigs under three months, as well as for some other kinds of swine, but not for hogs over three months old to be fattened for slaughter. This opinion is fully shared in this country. Yet in some countries, notably Canada, oats are a standard carbohydrate food for hogs.⁸⁸

Wheat is somewhat more valuable for hogs than corn, mainly owing to its higher content of protein. In experiments cited by Morrison,⁸⁹ 100 pounds of wheat were worth 107 pounds of corn (the price of tankage was again assumed to be three times that of corn). But caution is indicated in feeding wheat to hogs as to all other animals. In the bulletin of the Ministry of Agriculture and Fisheries of Great Britain, *Rations for Live Stock*,⁹⁰ ground wheat is recommended only "up to about $\frac{1}{4}$ of the cereal mixture. More than this is apt to make the food pasty and unpalatable."

Feeding rye to hogs requires still more care than feeding wheat. The Frenchman, Dechambre, like Kellner, insists that rye should be fed only in cooked form.⁹¹ Probably at most half of the grain ration may consist of rye, and the animals should be gradually accustomed to it. Kellner, who should

⁸⁶ In German experiments, results are usually less unfavorable for barley.

⁸⁷ O. J. Kellner, *Grundzüge der Fütterungslehre*, pp. 166, 167.

⁸⁸ H. E. Woodman, *op. cit.*, p. 10. Crampton, however, who made his studies under the auspices of the National Research Council of Canada, found corn more efficient for fattening hogs than oats, "oats being as valuable as corn for weanling pigs." According to his information also, "Partial substitutions of oats for corn not to exceed 25% of the grain, have been reported as preferable to a straight corn ration" (*ibid.*, p. 15).

⁸⁹ F. B. Morrison, *op. cit.*, p. 860.

⁹⁰ T. B. Wood, *op. cit.*, p. 44.

⁹¹ Paul Dechambre, *Traité de Zootechnie, Vol. IV, Le Porc* (Paris, 1924), p. 292.

know, does not mention that rye can be fed with advantage to little pigs. Yet Hansson, the Swedish authority, states that unground rye is an excellent feed for piglets.⁹²

An important point to be considered in connection with the selection of feeds for hogs fattened for slaughter is the quality of the finished products. When hogs (and other animals) are fed some fatty substance, part of the fat of the feed is deposited in their body without material alteration. If this fat is soft, the meat and fat of the animal fed is softened, and vice versa. Pure hog or beef fat is found only in animals fed fat-free feed. The hog fat is considered to be of excellent consistency, and its softening is believed to be undesirable. Hogs fed barley, which contains only a negligible amount of fat, are unanimously regarded as unsurpassed in quality. The quality of hogs fed rye or potatoes likewise containing little fat is about the same as that of hogs fed barley. On the other hand, the fat and meat of hogs fed peanuts, linseed, rice meal, and many other products are softened to such an extent that a substantial differential in price against such hogs exists. The fat and meat of hogs fed corn also are not so hard as those of hogs fed barley. The difference is the larger the younger the swine and the longer it was fed the particular feed before slaughter.

The above statements are supported both by extensive evidence from the practice and by experiments. The broadest such study, according to our knowledge, has been made in the United States.⁹³ In Great Britain the desire to reconcile the use of corn in hog feeding with the production of bacon of high quality induced the experts to make tests with degermed corn.⁹⁴ The results of feeding hogs degermed and not degermed corn showed a slight superiority of the bacon from hogs fed degermed corn. In those tests, however, corn con-

⁹² Nils Hansson, *op. cit.*, p. 105.

⁹³ See O. G. Hankins and N. R. Ellis, *Some Results of Soft-Pork Investigations* (U.S. Dept. Agr. Bull. 1407, April 1926).

⁹⁴ See Charles Crowther, "The Influence of Maize Germ on the Quality of Bacon," *Journal of the Ministry of Agriculture*, August 1932, XXXIX, 428-40.

stituted only 15 per cent of the ration for hogs weighing 30-70 pounds, 30 per cent for hogs weighing 70-140 pounds, and 40 per cent for hogs weighing upwards of 140 pounds. The difference in the quality of the products would evidently have been more pronounced if the rations, except for a protein supplement, had consisted of corn only.

The pork and fat of hogs fed corn are sufficiently hard to meet the requirements of consumers in the United States, and no premiums are paid for still harder products. But in Great Britain especially, and also in Germany and some other European countries, products of hogs fed corn are believed to be of decidedly inferior quality. An official British report shows, for example, that softness of the fat is seriously discriminated against in domestically produced hogs,⁹⁵ though among the feeds used in Great Britain for hogs corn probably is the one producing the softest fat. The English market seems to be especially particular in all its requirements as to the quality of pork and bacon, including firmness of the fat. A similar attitude is observed with regard to all meats.

European experts therefore warn against use of large quantities of corn for finishing hogs. British official experts are particularly reserved, consistent with the stronger requirements of the English meat market: "For fattening animals [hogs] when they have got a good start, up to $\frac{1}{4}$ of the cereal mixture may be replaced by maize meal or flaked maize. It is not advisable to go beyond this, as maize is reputed to produce soft fat."⁹⁶ The statement of Kellner is relatively favorable for corn:⁹⁷ "For hogs in the finishing stage more than half of the ration may consist of corn, particularly in the first half of the finishing period; still larger

⁹⁵ *Report on the Pork and Bacon Trades in England and Wales* (Great Britain Ministry of Agriculture and Fisheries, Economic Series 17, 1928), p. 90.

⁹⁶ T. B. Wood, *op. cit.*, pp. 43-44. The cautious attitude of experts in Great Britain toward corn as a hog feed is clearly revealed by the fact that in the experiment with degenerated corn noted above, the rations consisting of 15 to 40 per cent corn have been designated "liberal."

⁹⁷ O. J. Kellner, *Grundzüge der Fütterungslehre*, p. 103.

quantities result in oily fat and soft meat." Hansson writes:⁹⁸ "If corn is predominantly fed, the soft fat of the corn may soften the bacon." Dechambre expresses the opinion that⁹⁹ "Corn is primarily suitable for the finishing of large fat hogs." This seems to imply that in France corn is considered less adequate for the common type of meat and bacon hogs.

Hog producers naturally are even more reluctant than experts. Considerable premiums for barley are paid in Great Britain, Germany, and several other countries, in order to have at least part of the hog ration in the form of barley, especially in the last weeks of the finishing period. Probably a very large number of feeders do not use any corn if they can get the same poundage of barley for the same price.

No attempts have been made to explain the difference in the attitude toward hogs fed corn on the two sides of the Atlantic, as far as the writer is aware. The explanations offered below are tentative. In addition to differences in taste, the following factors seem to be important: (1) The feed seems to affect primarily the solidity of the fat, and here far more fat is removed from the carcass and not sold with the meat than is the practice in western Europe. (2) While in this country smoked bacon, ham, ribs, and the like are always broiled, fried, boiled, or otherwise cooked before serving, in most countries of Europe large quantities of these products are consumed without further preparation. Moreover, in Russia, and perhaps elsewhere, the conservation of fat is frequently limited to putting it in salt, and large quantities of such salted fat are eaten without preparation. (3) In some countries the weight of the slaughtered hogs is lower than in this country. The experiments summarized by Hankins and Ellis¹⁰⁰ leave no doubt that the softness of the pork products caused by feeding corn (or other feed containing oily fat) is considerably more pronounced in smaller hogs than in larger ones.

⁹⁸ Nils Hansson, *loc. cit.*

⁹⁹ Paul Dechambre, *loc. cit.*

¹⁰⁰ O. G. Hankins and N. R. Ellis, *op. cit.*, p. 57.

In some cases one of the enumerated points may suffice to bring about a substantial discrimination against hogs fed corn. Such an instance may be the consumption of fat without other preparation than salting. The same may be true of those cases where very young hogs are slaughtered. In Great Britain, for example, meat hogs commanding the highest prices are of less than 80 pounds dead weight (equivalent to approximately 100 pounds live weight).¹⁰¹ The softness of meat and fat of pigs of this age, if they are fed corn, would be a satisfactory reason for objection, though pork products are eaten in Great Britain in forms similar to those in vogue in this country. But there are sufficient indications that in Great Britain considerably more attention than in this country is paid to the solidity of the fat even with regard to hogs of slaughter weight that is not much different from the average weight of hogs slaughtered in many regions of the United States.

Feeding ruminants.—While oats do not command a high place as a hog feed (except for piglets and sows in pig), their competitive position rises as we turn to the feed of ruminants. The digestive power of these animals is so large that the high content of fiber in oats presents no obstacles. The British Ministry of Agriculture goes so far as to recommend farmers to assume that in the feeding of cattle and sheep one pound of oats is equivalent to one pound of barley.¹⁰² Oats are particularly liked for milch cows as well as for growing stock.

The fat of cattle and sheep is much more solid than that of hogs. In fact, it tends to be too solid for some uses. Hence the feeding of corn to beef cattle and sheep does not impair the quality of the beef and mutton and may even improve it.

Weber and Connel¹⁰³ present a summary of trials of the comparative value of wheat and corn for fattening cattle, made in different states, indicating that wheat alone is less

¹⁰¹ *Report on the Pork and Bacon Trades in England and Wales*, pp. 23-26, 31.

¹⁰² H. E. Woodman, *op. cit.*, pp. 10-11. The oats grown in cool, rainy Great Britain are of particularly good quality. See also pp. 128-32.

¹⁰³ A. D. Weber and W. E. Connel, *Wheat as a Fattening Feed for Cattle* (Kansas Agr. Exp. Sta. Bull. 261, November 1932), p. 6.

palatable than corn. According to their own experiments, also, the quality of the carcasses is reduced if wheat rather than corn is used as the only grain ration.¹⁰⁴ Trials at a number of experiment stations show, however, that half wheat and half corn yield somewhat larger daily gains in weight than corn alone.¹⁰⁵ Similar results were obtained by these writers with mixtures consisting of $\frac{2}{3}$ wheat and $\frac{1}{3}$ corn or $\frac{1}{3}$ wheat and $\frac{2}{3}$ corn.¹⁰⁶ These mixtures also produced carcasses comparable to those obtained when the grain ration consisted of corn alone.¹⁰⁷

Rye seems to be less objectionable as a feed for sheep than for other animals. Kellner¹⁰⁸ recommends a daily quantity up to $\frac{1}{4}$ kilogram (0.55 pounds) per head.

Feeding poultry.—A large proportion of the small quantity of wheat grain used for feed is fed to poultry, notably chickens.¹⁰⁹ The use of wheat for this purpose seems to be particularly widespread in Great Britain, the United States, Canada, and Australia. An inquiry of the United States Department of Agriculture on the feed used for turkeys showed that wheat was fed to them in every region, and in several states the quantities so fed were as large as those of corn.¹¹⁰

Part of the wheat fed to poultry is unsuitable for milling. Some wheat is fed on farms because the farms have no other suitable grain and use only small quantities at a time. But substantial quantities of millable wheat are bought for the purpose of feeding poultry, manufacturers of poultry feed feel it advisable to include wheat in their mixtures, and many

¹⁰⁴ A. D. Weber and W. E. Connel, *op. cit.*, p. 18.

¹⁰⁵ *Ibid.*, p. 8.

¹⁰⁶ *Ibid.*, p. 15.

¹⁰⁷ *Ibid.*, p. 18.

¹⁰⁸ O. J. Kellner, *Grundzüge der Fütterungslehre*, p. 103.

¹⁰⁹ Large amounts of millfeed also are fed to poultry.

¹¹⁰ ". . . in nearly all the areas approximately 100 pounds of corn was fed for each 100 pounds of turkey produced [dressed weight] . . . Approximately 100 pounds of wheat was fed per 100 pounds of turkey produced in the Mountain, Pacific, and West North Central States. Between 50 and 100 pounds of wheat were fed in the North Central and Northeastern States, but in the Southern States and in Texas less than 50 pounds was fed per 100 pounds of turkey produced." Marion Clawson, *Methods and Costs of Turkey Production, 1931* (U.S. Dept. Agr., Bureau Agr. Econ., mimeographed publication, February 1933), p. 3.

experts include wheat in the rations they recommend.¹¹¹ The writer is indebted to Professor E. T. Halnan, Cambridge University, for the information that in England "poultry keepers as a general rule insist on having wheat of good quality, and poultry wheat fetches as good prices as wheat sold for milling." The same seems to be true of this country. Since wheat generally commands a higher price than other grain, the use of large quantities of purchased wheat points toward a high evaluation of this grain as a poultry feed.

This large use of wheat as a poultry feed does not find sufficient support in scientific findings. The most favorable of them justify payment of a premium for such wheat that constitutes a moderate percentage of the feed, and some do not justify any premium at all. Thus Crampton, a Canadian expert, reports in substance¹¹² (1) that for chicks, more wheat than corn is required to produce equal gains, and chick mortality may be higher on wheat rations; (2) that for layers and breeders, wheat is about equal to corn for egg production and maintenance of body weight, that better hatchability of eggs produced on wheat rations has been reported in a few cases, and that there appears to be no difference in palatability between these grains; and (3) that for fattening stock, slightly more wheat probably is required to produce equal gains, and wheat-fed birds, though producing a white skin, do not yield as palatable a meat.

There still remains the possibility of rather considerable premiums for wheat as a poultry feed on the reasoning that (1) the best poultry feed is that consisting of several ingredients (this assumption is rather generally accepted), and (2)

¹¹¹ See, for example, the rations recommended for chickens by E. T. Halnan (*The Scientific Principles of Poultry Feeding*, Great Britain Ministry of Agriculture and Fisheries Bull. 7, 1936), and those recommended for turkeys in T. D. Bell and A. G. Macdonald, *Turkeys* (Great Britain Ministry of Agriculture and Fisheries Bull. 67, 1937), p. 17. A compilation of rations for laying hens in Illinois, Iowa, Missouri, New York, North Dakota, Oregon, Pennsylvania, Texas, and Virginia, all including wheat, is found in *Practical Experiences in Feeding Wheat* (Federal Farm Board Bull. 2, November 1930), p. 13.

¹¹² E. W. Crampton, *The Comparative Feeding Values for Poultry of Barley, Oats, Wheat, Rye and Corn* (Canadian National Research Council, Report 29, 1936), pp. 9-10.

wheat excels all the grains except corn as a poultry feed.¹¹³ The conclusions of Crampton,¹¹⁴ however, would indicate that wheat could be replaced by barley in the feed mixture without unfavorable results.

Outside the United States, the appreciation of corn as a poultry feed is in general materially less than in this country. Crampton writes:¹¹⁵ "The consensus of opinion is that barley and corn are equal for egg production when used in properly balanced rations." A British study¹¹⁶ reports "that, when used in fattening mashes, yellow maize tended to colour the flesh of the chickens." British consumers seem to be especially particular with regard to the color of their meats (see p. 61), but in the experiments cited corn failed also with regard to the gain per pound of feed.

The somewhat chaotic state of the knowledge on feeding poultry is indicated by the fact that ground oats are the standard fattening grain in Great Britain (and are sustained in this position by the results of experiments),¹¹⁷ while according to Crampton corn, wheat, and barley are more efficient than oats for this purpose. In the final analysis, such divergences in opinion may be caused by the simple fact that all grains, except perhaps rye, do not differ much for use as poultry feed, especially in mixtures in different proportions, except for some moderate variations caused by the differences in quality requirements for the poultry products.

¹¹³ This point of view is brought forward in "The Poultry Industry," *Agriculture Yearbook, 1924* (U.S. Dept. Agr.), p. 408.

¹¹⁴ E. W. Crampton, *The Comparative Feeding Values for Poultry of Barley, Oats, Wheat, Rye and Corn*, p. 9.

¹¹⁵ *Ibid.*, p. 8.

¹¹⁶ *Experiments in Table Poultry Production* (Great Britain Ministry of Agriculture and Fisheries Bull. 91, 1935), p. 47.

¹¹⁷ *Ibid.*

CHAPTER III

SCALES OF PREFERENCE¹

Consumers' preferences for different grains in various uses have already been touched upon in chapter ii. But that chapter, in the main, was devoted to suitability of different grains for different uses as determined by objective factors rather than subjective ones. In this chapter and the next, attention will be devoted to consumers' attitudes mainly. In this chapter our aim is to arrange the different grains, or the different uses of different grains, in scales as they rank according to consumers' preference in different countries and regions. So far as possible, this ranking is supported by an analysis of prices presented in this chapter and the next.

Preference for the use of a certain grain for a specific purpose is shown if the consumer is prepared to pay more for it (or expend more in its production if he himself is the producer and consumer) than for some other grain. But the observed prices do not necessarily show preference. Prices are the result of reciprocal effects of demand and supply. The price of malting barley might rise far beyond the price of wheat, if needed supplies could not be secured otherwise; but actually the whole demand for malting barley is frequently met for less than the price of wheat. Separating the effects of demand and supply on prices is the task of statistical analysis.

Statistically determined elasticity of demand shows the degree of consumer resistance to foregoing the use of some good when prices become high, either with or without substitution by another good. Other methods of mathematical analysis demonstrate the price conditions under which the consumer is prepared to substitute one good for another. Unfortunately,

¹ Thanks for valuable suggestions are due to Dr. B. F. Haley of Stanford University, Dr. Sidney Hoos of the Giannini Foundation of Agricultural Economics, University of California, and Dr. O. Strange Peterson of the University of Aarhus, Denmark.

such analysis of the demand for grains other than wheat has thus far yielded little, owing to the inadequacy of the data (see pp. 82-83) and probably also of the procedure used. To reach some conclusions, it is mostly inevitable to resort to a less refined analysis of the price and supply data, in spite of the risk of error involved in such an analysis.

Moreover, nonstatistical observation of the market becomes an important source of information under these conditions. The reliability of this source should in no case be minimized. Careful observation of the market over years often makes it relatively easy to arrange in a scale the preferences for such similar goods as grains, especially for specific uses and specific regions. Yet this ease is encountered only with regard to qualitative characteristics. Quantitative evaluations are much more difficult, for preferences are based mainly on subjective rather than on objective criteria (see p. 25).

It can be expected, for example, that feed barley as hog feed will be evaluated by the hog raiser (in the economic sense the consumer) in the United States at about 5 per cent less than corn. This is because the content of nutrients in barley is less by about this percentage, and because in this country there is no discrimination against the quality of the pork and fat of corn-fed hogs as compared with the pork and fat of barley-fed hogs. Similarly, oats should be valued at about 15 per cent less than corn (in accordance with their lesser content of nutrients) for the use of animals for which oats have no specific advantages. So far as wheat and rye as material for breadmaking are concerned, the probable spread in evaluation can be determined quantitatively without resort to mathematical analysis only where there is no preference in favor of wheat or rye flour. In this case the excess of the value of wheat is determined solely by the difference between the value of the additional flour extracted from the wheat kernels and an equal amount of wheat bran.

This is about all. The preference for barley over rye as

hog feed, for example, is due, where rye does not constitute more than half of the ration, primarily to the additional care needed in feeding rye. The disadvantages involved may be evaluated by the feeders at anywhere from 5 per cent to perhaps 25 per cent (and even more) of the price of barley. The preference of consumers for wheat bread as against rye bread, or for one type of porridge as against another type, may be equivalent to 20 per cent of the price of wheat or to 100 per cent of the price of the porridge grain.

Scales of preference exist for specific uses of specific grains, rather than for grains generally. If scales are established not only for such specific uses of specific grains, but also for specific grains in general or for broader groups of uses, it is either because practically the total supply of a certain grain or the total supply of food or feed grain respectively is used for one specific use only, or because the place of a certain grain in the general scale of preference or in the scales as food or feed respectively is regularly determined by some specific use which ranks below other uses of the same grain. For example, since the supply of corn usually is vastly greater than the demand for food, its food demand may be disregarded in the ranking. Moreover, the supply of corn in many countries is much greater than the amount wanted for poultry feed, and the rank of corn as feed is commonly determined not by its high value as part of poultry feed, but by its lower-ranking value for, say, dairy cows.² On the other hand, the feed value of wheat, which usually is available only for the higher-ranking feed uses, is mostly determined by its high value as a portion of the grain ration of poultry.

Use of grains for food must be ranked above use for feed. The reason for such ranking is found in the fact (pp. 25-27) that the elasticity of demand for grains in the use as food in

² Though the first unit of corn used as poultry feed may have a higher utility than the first unit of corn used as a feed for dairy cows, the utility of the tenth unit of corn in the former use may be lower than that of the first in the second use. Such refinements have to be omitted here, and the use of corn as chicken feed is accepted as having a higher place in the scale of preference than its use as feed for dairy cows.

general, and the ease of substitution of one food grain for another, are more limited than is the case with the use of grains as feed. Since a higher ranking of the uses as food is accepted, all we need is first to rank the uses as food and as feed, and then place the one series above the other.

One can be rather positive that wheat in the use for food in the narrow sense (not including drink) ranks above any other grain here studied in consumers' preferences, at least so far as the effect on prices of the particular grains is concerned. The demand for a specific type of porridge is likely to be as inelastic as the demand for wheat as food merely in countries with small per capita consumption of porridge, i.e., under conditions where it seldom can be significant as a price factor. Such effect, if any, tends to be limited to that on specific types or grades of specific grains. On the other hand, where consumption of porridge is large, and this demand is likely to affect prices of these grains, the demand for specific types of porridge is relatively more elastic. Porridge in large quantities is consumed only by poor populations, such as the Russian. Moreover, porridge in such quantities is largely consumed because it is a cheap food, and price changes cannot fail to affect materially the consumption of each specific type of porridge. The extent of substitution of other grains for wheat or wheat for other grains in such countries is also substantially larger, it is true, than for example in the United States. But displacement of one type of porridge by another type may be even larger. The situation with regard to the use for flatbread is similar to that for porridge.

While wheat as food is preferred to all other cereal grains, malting barley plays the same role among grains used for beverages. Barley used in the preparation of beer is practically irreplaceable by any other grain, or good, and even substitution of one type and grade of barley by another is rather limited. Moreover, the demand for malting barley in several important countries is so large as to elevate the market for malting barley to a very prominent position. The demand for

specific grains (corn, barley, rye) for liquor, on the other hand, even in those rare cases where substitution is very limited, is seldom sufficiently large to affect considerably the prices of the specific grains, especially since the requirements can be satisfied with any type or grade of the respective grain.³

Thus it seems proper to put the uses of wheat and of barley for food and drink respectively at the top of the scale. Data in Charts 2 to 4 (pp. 10-12) in fact show that the average prices of wheat are only rarely below those of any other grain except malting barley. Moreover, in all exporting countries and in the so-called world markets, a margin more or less wide commonly exists between the prices of wheat and those of the other grains except malting barley. Where these margins are small, wheat of less desirable quality for bread-making as, for example, wheat produced in northwestern and north central Europe, is mostly involved. But the margin is frequently large, in spite of the poor quality of the wheat.

Where substantial quantities of a grain other than malting barley are demanded at a price higher than that of wheat, some exceptional reasons prevail. California is one of a few such cases. In 1932-33 to 1936-37, corn in San Francisco averaged 4.5 per cent above white wheat in price, and in 1934-35 corn was more expensive than wheat by as much as 22 per cent. California wheat is a type little liked for bread production, while large quantities of corn are urgently demanded for the huge California poultry industry; the inelasticity of the demand for corn as a poultry feed seems to be more marked in California than in all but a few other places. Yet natural conditions of California, fairly suitable for the production of wheat, are unfavorable for corn. So are wide stretches of land north and east of California.

Unfortunately, it is not often possible to classify the prices of barley shown in Charts 2 to 4 into those respectively for

³ To avoid confusion, it is well to recall that wheat, rye, barley, and the like are different *kinds* of grain; hard, soft, red, white, and the like are *types* of wheat. Each type is subdivided into *grades*. The official grading systems of the United States and Canada use the designation *class* rather than type.

malting and for feed barley. So far as prices of malting barley are definitely specified, they tend, like wheat prices, to be materially above those of all grains other than wheat. In the province of Brandenburg, Germany,⁴ malting barley averaged 32 per cent dearer than feed barley in 1909-13, and 18 per cent dearer in 1925-29. In Victoria, Australia, farm prices of malting barley on the average were higher than those of feed barley by 55, 24, and 45 per cent in 1909-13, 1925-29, and 1930-33, respectively. The price of "shipping barley" (i.e., malting barley) in San Francisco exceeded the price of feed barley by 16.5 per cent on the average in 1925-26 to 1929-30, because of the customary scarcity of feed grain in California. In the British markets to which Californian barley is shipped, its price usually exceeds the price of feed barley by a wider margin than in California.

It remains to decide whether wheat as food or malting barley ranks the higher. The effect of changes in the price of barley on the cost of beer is much less than the effect of changes in the price of wheat on the prices of bread. This fact may tend to make the demand for malting barley less elastic than that for wheat. On the other hand, the substitution of other barleys for malting barley is much more easily accomplished than is the substitution of other grains for wheat as food.⁵ Wheat prices more frequently exceed than fall below the prices of malting barley. Moreover, the price difference is sometimes considerable, the prices of malting barley being near the prices of feed grain. Under conditions of shortage, however, malting barley skyrockets more easily than wheat. In some years of poor harvests, malting barley of medium quality and below sells for much more than the best wheat in Eastern markets of the United States. In Great Britain in recent years, an agreement between brewers and

⁴ Brandenburg is the province of which Berlin is the capital. The quotations at Berlin pertain to grain in carloads free-on-rail at the stations of that province.

⁵ An additional reason for this greater ease is that the substitution of one barley for another is made by manufacturers, while the substitution of other grains for wheat mostly needs the participation of the consumer. Using flour other than wheat in the preparation of wheat bread mostly is adulteration in the legal sense.

the government regarding preferential use of domestic barleys at prices remunerative to growers has been largely or wholly responsible for the fact that the average price of all domestic barley was 42 per cent above the average price of domestic wheat in 1932-36 (Chart 3, p. 11). Good malting samples have sometimes fetched twice as much as good domestic wheat, and even considerably more.

So far as there are differences in the ranking of wheat and malting barley, national incomes seem to have some influence on these differences. In countries with a very low standard of living, consumers are prepared to make the money sacrifice involved in having small amounts of wheaten products, while being unable to be particular with regard to the quality of their beer (which is sometimes homemade). Any barley, not excluding that "unsuitable for beer production," is used for beer under these conditions. But habits also are evidently of great significance in this connection. A Bavarian is used to bread of moderate quality, but is not satisfied with a beer poorer than one of the best in the world.

Owing to the uncertainty as to the mutual positions of wheat as food and malting barley in the scale of preference, it seems advisable to assign to these grains the first two places in the scale, not specifying which ranks first and which second. This indefiniteness makes it unnecessary to vary the ranking of these two uses for different countries. Such modifications are, however, indispensable for other uses of grains. Moreover, it seems advisable to proceed gradually in the analysis of the ranking of uses other than the two named, starting from the situation in specific countries or regions.

RANKING IN THE UNITED STATES

As to corn, oats, and barley other than malting barley, only the use as feed need be considered for the United States as a whole. The food uses absorb too small proportions of the total supplies of these grains to affect prices sensibly. Thus with the first two places occupied by malting barley and wheat,

rye has no competitor for third place, so long as there is enough demand for rye for food and liquor.⁶ But the small domestic demand for these purposes is easily satisfied except in years of exceptional drought, while a large export demand for American rye for food purposes tends to be present only in periods of war and postwar scarcity.

With reference to use for feed, the first two places in the ranking of feed uses of grains in the United States we would assign to oats for a large portion of the grain ration of horses, and to wheat for a portion of the grain ration of poultry. Then comes corn. It ranks third only because the supply of corn usually is so large that the preferential use of corn as a poultry feed, for example, does not affect prices except locally.⁷ Feed barley follows corn. Wheat, in all uses except for a portion of the grain ration of poultry, must be ranked approximately as high as feed barley. A similar rank may be assigned to oats except in the use for horses mentioned above.⁸ Rye as feed in this country cannot claim more than last place. Thus the scale of preference for the United States will be: 1 and 2, malting barley and wheat as food; 3, rye as food and for liquor; 4 and 5, oats for a large portion of the grain ration of horses and wheat for a portion of the grain ration of poultry; 6, corn; 7, 8, and 9, oats and wheat, in all uses as feed except those already mentioned, and barley; and 10, rye as feed.

Even in our rather rough scale of preferences, every grain occurs twice, but at a given time it mostly has only one price. Hence the scale can be reflected in prices only very broadly.⁹ Charts 2 and 6 (pp. 10 and 87) show that, with rare excep-

⁶ The demand for rye for liquor should probably even be ranked as high as that for malting barley.

⁷ See p. 71 on the situation in California.

⁸ There are reasons to rank the use of wheat other than for poultry somewhat above the use of barley as feed and the use of oats for certain uses under the latter, but such minute distinctions are dispensable here.

⁹ The shifts of the market prices from the evaluation for a certain use to an evaluation for a higher or lower ranking use, for example, from the evaluation of rye as a bread grain to that as a hog feed, greatly complicates statistical analysis of relations between total disappearance and average prices.

tions, wheat in the United States is more expensive than rye, corn, or oats. Poultry feeders are eager to use wheat at prices substantially above feed-grain prices; the practice of using a large proportion of wheat in the "grain scratch" mixture is so firmly established that wheat is omitted in hardly any brand. Thus nothing ordinarily prevents wheat from being evaluated according to its rank in the scale of consumers' preferences as food.

Unfortunately no price series of malting and feed barley in the eastern United States are available.¹⁰ But doubt can exist only as to the relative positions of the prices of wheat and malting barley, for malting barley clearly exceeds in price all grains other than wheat.

The preference for oats as horse feed could seldom affect prices in postwar years in the United States, for commonly the supply of oats has far exceeded this demand. But in the fifteen years before the World War oats in Chicago were some 20 per cent more expensive than corn in spite of their markedly lower content of nutrients. The preference for oats over barley as a horse feed is also clearly demonstrated by the fact that wheat farmers in some important drier regions grow oats for their horses, although barley yields better and in the spring-wheat regions has also some rotational advantages as compared to oats (see p. 320).

In postwar years the tendency in the United States seems to have been definitely for corn to be the highest-priced feed grain, in spite of its low cost of production (see chapter xvi); and it has actually reached this position in recent years. In the five years ending in 1936-37, the price of No. 3 corn at Chicago exceeded the price of No. 3 oats at Chicago by 10 per cent. No. 3 corn in Chicago was also 5 per cent more expensive than No. 2 rye in Minneapolis.¹¹ In spite of the absence

¹⁰ For scattered data on prices of malting barley, see pp. 105-06.

¹¹ Because of the location of Minneapolis, its rye prices can be only slightly less than those of Chicago, since the predominant part of the rye-producing section in North Dakota can ship at the same rates to Minneapolis and to Duluth. Moreover, No. 2 is a better grade of rye than No. 3 is of corn.

of series of prices of feed barley for the eastern United States, we are rather confident that feed barley tends to be cheaper than corn. In the five years ending with 1936-37, farm prices of barley and rye averaged the same in North Dakota, where most surpluses of rye and considerable surpluses of feed barley originated (Chart 2, p. 10); and corn was 32 per cent higher than either. In Iowa, farm prices of corn in the same five years were only 5 per cent under those of barley, in spite of the immense supplies of corn and negligible supplies of barley.

Since the Chicago price of oats pertains to No. 3 and that of Minneapolis rye to No. 2, rye may even have been cheaper than oats in these five recent years. But the supplies of rye occasionally were not much in excess of the demand for food and similar higher-ranking uses with a corresponding effect on its price. Hence the inference can be drawn that rye as a feed grain ranked lowest in price. Data at hand do not permit a more exact statement than that in the last few years oats and feed barley have brought approximately the same prices.

Thus feed grains in the United States rank according to prices, from high to low, as follows: corn, oats and barley, and rye.

RANKING IN EUROPE

The simplest situation in Europe is met in the northwestern corner, where wheat is the only important food grain other than malting barley. The ranking of feed grains is somewhat different from that accepted for the United States. The preference for oats as a horse feed is even more pronounced than in the United States. In England, moreover, oats are preferred for finishing poultry for the market. Oats seem to enjoy preference also with regard to certain other uses both in England and some other countries. For a portion of poultry feed, wheat is at least as preferred in Great Britain (perhaps also in some other countries) as in the United States. It is most pertinent that barley is definitely preferred to corn at

least for a large portion of hog feed. It is difficult to find out whether feeders would be prepared to pay higher prices for corn than for other grains in the use for part of the poultry feed, because supplies usually far exceed the requirements for this need; but the evaluation of corn as a hog feed is in any case sensibly lower than in the United States. The position of rye as feed in Europe is in general not so low as in the United States. The additional care involved in using rye as feed weighs less with a European feeder than with an American one. Yet in northwestern Europe rye possibly still ranks last as feed.

Thus the scale of consumers' preference for northwestern Europe is: 1 and 2, malting barley and wheat as food; 3, 4, and 5, oats for much of the horse feed, for finishing poultry in England, and for some other uses, barley for most of the hog feed, and wheat for part of the poultry feed; 6, 7, 8, and 9, oats, barley, and wheat for uses except those already mentioned, and corn for feed; and 10, rye as feed.

Moving eastward into the northern portion of central Europe, we find the same ranking as farther west except that in north central Europe rye retains its role as a food grain, though in a rather shaken form; so large a portion of the rye crop generally has no outlet other than feed that this exerts a strong influence on the price of rye. As to the position of rye as feed, it is important that in several countries feeders are well used to it. Many of them may consider a substantial proportion of rye not a worse feed than some other lower-priced feed grain.

In southeastern Europe, rye as a food grain must again be omitted from the ranking and corn as food introduced. The same seems to be true of portions of Italy and Spain. The ranking of grains as feeds may also be somewhat different from that in northwestern and north central Europe, owing to the greater familiarity with corn and barley (the latter as a horse feed).

The ranking of the five grains in prewar Russia was about

the same as that in north central Europe (see the prices in Odessa in Chart 2, p. 10). Some difficulty would be involved if buckwheat and millet were included in the Russian scale of consumers' preference. Those grains are definitely food products in Russia. Their ranking is difficult because the use of kasha (porridge) is supplementary to that of bread. The prices paid by consumers for the groats used in the preparation of kasha and for the grains used in the preparation of the groats may give an idea of the position of these grains. On the average in 1901-10, the following wholesale prices, in kopeks per pood, were quoted in Moscow:¹²

Buckwheat groats (<i>jadritza</i>).....	139.9
Millet groats, Orenburg.....	137.9
Millet groats, various origins.....	113.2
Rye flour, sifted (about 60 per cent extraction)....	123.3
Wheat flour, best quality.....	204.0

The ranking of the grains from which the flour and groats were made was similar. Thus, so far as average prices of ten normal years may be expected to reflect correctly the ranking according to consumers' preference, the ranking for grains as food in prewar Russia was: 1 and 2, malting barley and wheat; 3, buckwheat; 4, rye; and 5, millet.

GENERAL SCALE

The scale of grains according to consumers' preferences accepted for the northern portion of central Europe is also valid for the international trade in grains. This we are therefore inclined to use as a general ranking. It runs as follows: 1 and 2, malting barley and wheat as food; 3, rye as food; 4 and 5, oats (for most of the horse feed and small parts of some other uses) and barley (for a considerable part of the hog feed); 6, 7, and 8, oats and barley for uses as feed except those mentioned under 4 and 5, and corn as feed; and 9, rye as feed.

World market prices of oats and feed barley were so close to one another, in each of the three periods specified in Chart 3

¹² *Recueil de données statistiques et économiques sur l'industrie agricole en Russie et dans les pays étrangers* (already cited), pp. 451-53.

(p. 11), that it is not clear which of the two grains was the more expensive. But if world market prices for longer periods (Chart 5, p. 86) are used, prewar prices of oats appear 3 to 5 per cent higher than those of feed barley, whereas in postwar years barley averaged about 7 per cent above oats in price.¹⁸ This price reversal seems correctly to reflect the changed demand situation. Prewar oat prices were mostly on the basis of evaluation as horse feed, whereas in postwar years oat supplies tended to be greatly in excess of this demand. Feed barley, however, was priced according to its high ranking as a hog feed, both in prewar and postwar years.

Corn was the cheapest grain on the world markets in all three 5-year periods (Chart 3, p. 11). In the fifteen prewar years (Chart 5, p. 86), corn prices were less than the prices of feed barley by 6 per cent and less than the corrected oats prices by about 11 per cent. In 1925-26 through 1936-37, corn prices in world markets even averaged 15 per cent less than barley prices and 8 per cent less than oats prices. Part of these price differences is caused by the fact that almost all the oats and a large part of the barley, that are fed to animals on farms in the importing countries, are produced on the farms where fed. Corn, however, is an imported product, and the world market prices used in Charts 3 and 5 are c.i.f. prices, i.e., they do not include costs of delivery within the country of destination.

Double marketing costs, which are involved if the farmers sell their own grain and buy another one instead, encourage the use of farm-produced grains and support the farm prices of such of these grains as can be used on the farm, while making possible materially lower prices for the kind of grain imported, particularly when supplies of this are excessive (see

¹⁸ The prewar prices in Chart 5 indicate a larger difference between oats and barley prices than 3 to 5 per cent. But the prices of oats probably ought to be reduced by a few per cent (perhaps 3) to be comparable with prices of the other grains. The prices of oats are for Cologne, Germany, while the corn prices are for London and the barley prices for Bremen, Germany. The marketing costs from exporting countries to Cologne are higher than those to London and Bremen approximately by the cost of transportation from Rotterdam to Cologne. Moreover, the manner of computing the prices of corn (averages of lowest monthly prices of corn of three different origins) tended to depress their level slightly.

chapter vi for details). But the fact remains that in importing countries with import duties on corn not higher than those on other feed grains, feeders who buy their feed could almost always get corn cheaper than either feed barley or oats. Only part of this price spread, however, is explained by the failure of consumers to realize the feeding value of corn. The low cost of production of corn in Argentina and the large exports from that country caused corn to tend to be priced according to its value in lowest-ranking uses.

Recognition of the high value of corn as feed apparently made substantial progress in importing countries after the World War. It is irrelevant that the relative position of corn prices on world markets in the five years ending in 1929 was not better than in the five years before the World War and that in the five years ending in 1936 it was even materially worse (Chart 3, p. 11). World exports increased so greatly relative to total world exports of feed grains (see data on world net exports, Chart 53, p. 459, and Table V) that the former margin between the prices of corn and the other feed grains could not be sustained, in spite of the growing appreciation of corn by consumers.¹⁴

World market prices of rye in the prewar and predepression 5-year periods were above those of oats and barley (Chart 3). But the price difference was substantial only in the predepression period, when the supply position of rye was particularly favorable to rye. In the five prewar years, world market prices of rye exceeded those of oats and barley only by 7 per cent, although the prices used for rye were those of high-priced Russian sorts. The low-priced German rye in import markets averaged hardly more than imported oats or feed barley. In 1932-36 the small supply of export rye exceeded the import demand for rye as food to such an extent that average world prices were below those of either oats or feed barley. The prices of the sparingly offered export rye were higher only than those of the abundantly offered corn.

¹⁴ See further, below, pp. 191-92.

DEMAND ELASTICITY AND SUBSTITUTION

Consumption of a certain food over a very long time due to its cheapness may lead to the establishment of a preference such that consumers may be prepared to make considerable sacrifices to obtain this food during short periods of scarcity. Thus there may be important differences between the response of consumers to sustained changes in price relationships and their response to short-run price changes. But with the preferences unchanged, the short-run and long-run behavior of consumers are largely interconnected. Consumers who refuse to substitute any other bread for wheat bread in the short run can be expected to stick tenaciously to wheat bread in the long run also. Feeders who are prepared to substitute barley for corn for their hogs when for a month barley has been 20 per cent cheaper than corn on a poundage basis would presumably make the shift at a price stimulus smaller than that if it continued for several months or years. Responses of consumers to short-run price changes indeed throw so much light on the attitudes of consumers to goods—attitudes which for the time being may be considered permanent or constant—that it would be a loss to clarity not to use information on the response of consumers to short-run price changes, even though our study is concerned with long-time phenomena only.

An additional reason for including such information in our analysis is that the concepts of demand elasticity and of substitution of one consumers' good for another, and reliable methods of determining them, are developed mainly for short-run phenomena.¹ However, in order that the analysis of con-

¹ R. L. Mighell and R. H. Allen, in their "Demand Schedules—'Normal' and 'Instantaneous'" (*Journal of Farm Economics*, August 1939, XXI, 555-69), usefully stress the necessity of segregating consumers' behavior at "instantaneous" price changes and at "normal" price levels and spreads. However, when they insist that the significance of "the time-consuming character of shifts in consumption . . . has been generally overlooked in practice" (p. 558), they seem to go too far.

sumers' responses to short-run price changes should not mislead, the fact must be constantly kept in mind that the short-run behavior of consumers' demand may differ—at least quantitatively—from the responses of consumers to sustained changes in price relationships.

Unfortunately our knowledge of the elasticity of demand² for grains and of substitution between grains and other products and between grains themselves—even in the short run—may be called satisfactory only with regard to wheat. Recently Timoshenko made a daring attempt to isolate monetary influences from other factors which have been responsible for changes in postwar wheat prices.³ Better estimates of the utilization of wheat and, consequently, better estimates of the year-end carryovers of wheat for the postwar period—resulting from careful analysis of market statistics by the Food Research Institute—made possible the isolation of those price movements which could not be explained in the light of the supply-demand relationship and which could be attributed partly to monetary influences.

No data are available on other grains which would permit an analysis like that undertaken by Timoshenko for wheat. But the fact that data on grains other than wheat are much less conclusive is primarily a reflection of a much more complicated actual situation. The demand for wheat as food is likely to be more inelastic than the food demand for all or most other grains. Moreover, almost all wheat is used for food. Thus the strong demand inelasticity of wheat in the use as food implies strong demand inelasticity of wheat in general. Under such conditions wheat constitutes broadly an independent market. With considerable success the Food Research Institute has concentrated attention on wheat for nearly two decades, with only occasional side-glances at other grains.

² Elasticity of demand measures the change in quantity demanded in relation to unit change in price.

³ V. P. Timoshenko, "Monetary Influences on Postwar Wheat Prices," *Wheat Studies*, April 1938, XIV, 263-318.

Such an almost isolated analysis would have failed in any other grain except probably rice.

Large but greatly varying proportions of rye are used as feed. The price of rye may be based entirely on its value as food for some time, and then again on its value as feed, with all possible types of intermediate positions. Malting and feeding barley rank quite differently in consumers' preferences. Any attempt to get usable conclusions from a statistical analysis of total supplies and average prices of all rye or all barley is likely to be doomed to failure. But there are no means of segregating the supplies of different barleys, and even the difficulties of procuring long-time series of prices of different types of barley cannot always be overcome.

Demand elasticity and substitution in the feed-grain markets differ materially from those in the food-grain markets. The total demand for feed grain is more elastic than the total demand for food grain and even than the food demand for most grains separately. The number of consumers of food and their average age change slowly, in a known direction, and at approximately the same rate from year to year. Live-stock numbers and their average ages, however, not only change more or less violently, owing to the changes in demand for animal products, but are altered for the specific purpose of adjusting them to the supplies of feed. Moreover, the demand for feed grain depends to a much larger extent on the supply of other feeds than is true of the demand for food grain, and no statistical data are available on the year-to-year changes in production of grass in pastures. Not only is the total demand for feed grain more elastic, but also the substitution of one feed grain for another is much wider than substitution between food grains. In fact, while the expression food-grain market is hardly correct and one probably ought to speak of as many markets as there are food grains, the expression feed-grain market correctly represents the actual situation.

IN FOOD USE

Wheat: in general.—The human diet has undergone fundamental changes with the passage of time. The more recent tendency in the civilized world has been toward substantial contraction of the per capita food consumption of cereals. This has brought important setbacks for all grains, not excluding wheat. Wheat, however, has tended to be substituted for all other grains in breadmaking, and no long-run instance can be cited when another kind of bread has been substituted for wheat bread. The same is true of the other uses of wheat as food (cakes, alimentary pastes, and the like). With perhaps some negligible exceptions, wheat as a food has not had to give way to another grain for a long period of time.

In the short run, the demand for wheat as a food is in general extremely inelastic. Great contractions of income prove more effective in bringing about reductions than high wheat prices. The extreme inelasticity also leaves little room for substitution by or for other grains. Shifts from wheat to rye bread, corn flatbread, or other even cheaper sources of carbohydrates (in many countries of central and northern Europe potatoes are frequently cheaper than rye bread) occur only in emergencies. Temporary increases in wheat consumption probably more frequently occur because coarse grains are dear than because wheat is cheap. It is only in poor countries such as Russia, China, and British India that the demand for wheat shows a sensibly lesser inelasticity and certain other grains are more readily replaced or substituted by or for wheat. Not only do the price of wheat and the price spreads between wheat and the other grains have a certain effect on the volume of wheat consumption in such countries, but the volume of production as such affects consumption, many producers varying their consumption with the variations in the outturn of their fields.

Substitution of some other grain for wheat in the Western world in general encounters strong objections even in the relatively mild form of a small admixture of other flours in

the preparation of wheat bread. Such small admixtures as 5 to 10 per cent are objected to so vigorously that they have to be made compulsory by governments when believed necessary. The only form of substitution which meets with little objection from consumers is a change in the proportions of wheat and rye flours in mixed rye-wheat bread, or of wheat and corn in mixed corn-wheat bread. Moderate changes in the composition of this mixed bread may even pass unnoticed. In the countries where rye and corn still play an important role in human food and where a substantial proportion of rye or corn is consumed in the form of mixed bread, changes in the composition of mixed bread may result in small variations in total wheat requirements. They are almost negligible, however, for the world as a whole.

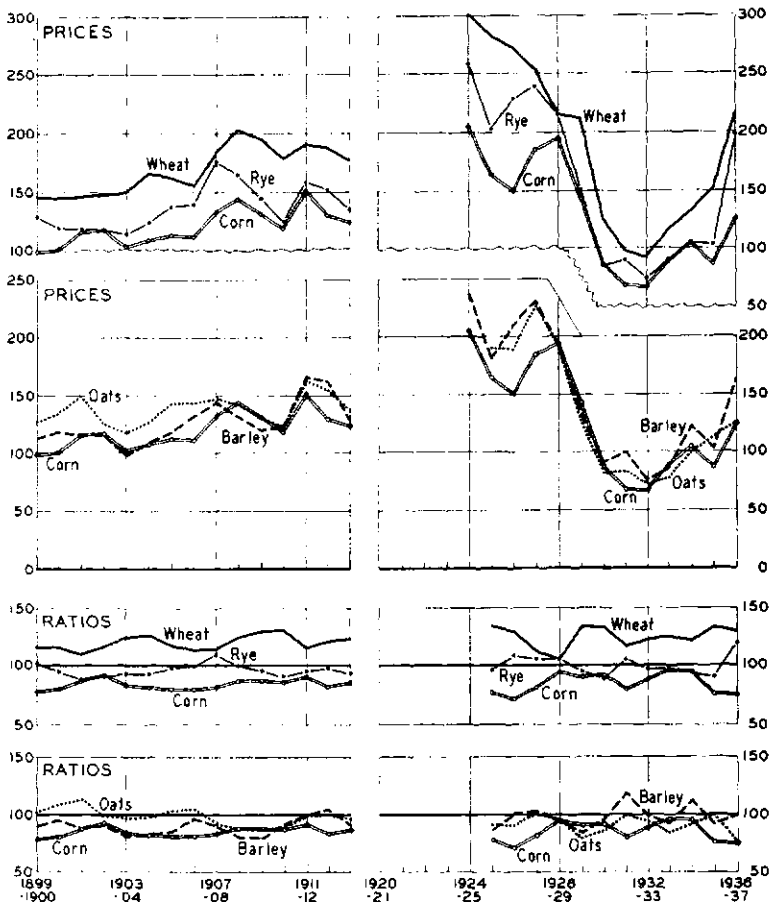
Holbrook Working has found that the elasticity of per capita demand for wheat flour in the United States was only $-.02$ in the nine years 1921-22 to 1929-30. Moreover, in his opinion, "Even this negligible degree of elasticity is largely or wholly spurious . . ." Data on apparent utilization (production minus net exports plus or minus changes in stocks) of wheat, which includes both food and feed use, though likewise showing a considerable degree of inelasticity of demand, yield coefficients of elasticity many times as high. In the same paper, Working obtained for apparent utilization of wheat and Chicago cash prices in 1896-1913 the coefficient of elasticity of demand of $-.36 \pm .21$. The findings of Henry Schultz are similar.⁵

Moreover, the concept of elasticity of demand is based on the assumption of constant income. The consumption demand for a good is elastic if a certain change in price of the good brings about a larger change in its consumption without any change in incomes. A demand is still regarded as inelastic if contraction in consumption is the result of

⁴ Paper presented before the Econometric Society at Chicago, December 1936. The writer is indebted to Dr. Working for permission to quote from a manuscript as yet unpublished.

⁵ See his *The Theory and Measurement of Demand* (Chicago, 1938), p. 400.

CHART 5.—WORLD MARKET PRICES OF GRAINS, BY YEARS, PREWAR AND POSTWAR*
 (Prices, in cents per cental; ratios, to simple average price of all grains except barley)

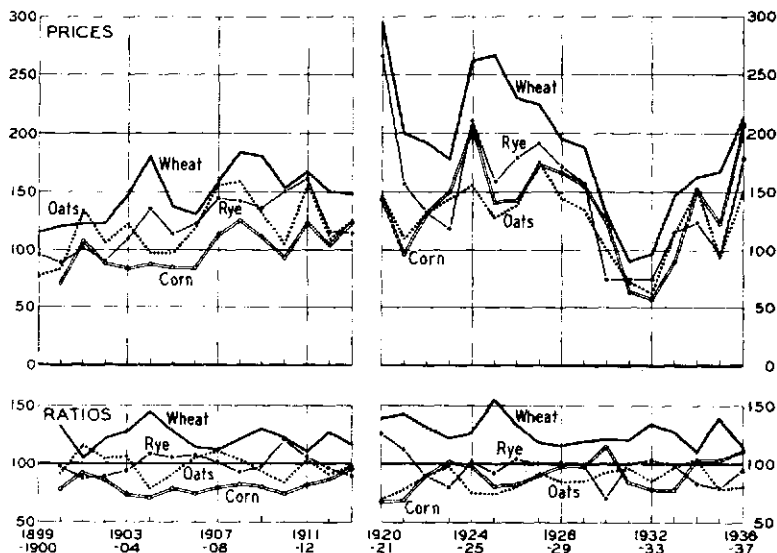


* Prewar basic data are from (a) U.S. Dept. Agr., *Agriculture Yearbook*, 1923, p. 630 (Broomhall's series for red imported wheat of fair quality at Liverpool); and (b) *Vierteljahrshefte zur Statistik des deutschen Reichs*, as follows: Russian rye and barley at Bremen; imported oats (primarily Russian and Argentine) at Cologne; and yearly averages of lowest monthly prices of corn from the United States, Argentina, and Odessa in Great Britain.

Postwar basic data include Food Research Institute series of British parcels prices of wheat, and prices of other grains from *Konjunkturstatistisches Handbuch*, 1936 (Institut für Konjunkturforschung, Berlin, 1935), and *Wirtschaft und Statistik*, as follows: up to 1932, American or Canadian No. 2 Rye at Rotterdam; in later years other imported rye (probably mostly Argentine rye) at the same market; Argentine f.a.q. oats at London; Argentine corn at Hamburg.

CHART 6.—PRICES OF GRAINS IN THE UNITED STATES, BY YEARS, PREWAR AND POSTWAR*

(Prices, in cents per cental; ratios, to simple average price of all grains)



* Basic Cash Wheat, No. 2 Rye, No. 3 White Oats, and No. 3 Corn in Chicago (in postwar years, No. 2 Rye at Minneapolis). August-July years except as noted. Data of the Department of Agriculture, except that rye prices for the first five years (July-June) are from the *Report of the Federal Trade Commission on the Grain Trade* (Washington, 1924), VI, 33, and the remaining prewar data are from the *Annuaire International de statistique agricole, 1911-12*, p. 611, and *ibid.*, 1913-14, p. 490.

It seemed preferable not to include barley prices, since none of the available series is representative for feed barley or for malting barley. Series of prices of distinct barleys of some length are available only for California, but they cannot well be used here.

reduced incomes. But at such high income levels as those attained in the United States, per capita consumption of wheat flour is largely independent even of changes in income. Such extreme drop in incomes as occurred in the recent depression exerted only a small effect on the per capita consumption of wheat flour, the contraction by 16 per cent from 1929 to 1936 having been primarily a continuation of the declining long-run trend, according to Working.

The elasticity of the demand for wheat as food in such countries as Great Britain or the Netherlands seems to be

little greater than in the United States, according to data assembled by Working. In many countries the elasticity of the food demand for wheat is larger than in the United States and Great Britain, and in such countries as Russia, China, and British India it is undoubtedly much larger. Yet even in the latter countries, the demand seems to remain quite inelastic. The demand for wheat in the world wheat market in any case proves very inelastic.

A glance at the prices of different grains in the world market (Chart 5, p. 86) reveals a large degree of independence of wheat prices; with few exceptions, these move far above the prices of all other grains. Moreover, wheat has also been largely independent of the other grains in year-to-year changes of price.

Let us first compare the prices of wheat and feed grains. The highest world market prices of wheat in the fifteen pre-war years occurred in 1908-09. Prices of oats, barley, and corn, however, were highest in 1911-12. The lowest price of wheat occurred in 1900-01, of oats and barley in 1903-04. Only the lowest price of corn happened to come at approximately the same time as that of wheat. In 1911-12 the price of wheat on the world markets rose from the preceding year by only 6.9 per cent, while the prices of feed grains increased on the average by 31.6 per cent. In 1903-04 feed grains fell by 11.5 per cent, but wheat rose slightly. Moreover, a large part of the positive correlation in the price movements of wheat and feed grains, probably almost all of it, was the result of a similar correlation in the changes of supplies.

What was demonstrated by the relationships between wheat and feed-grain prices was probably equally true of the relations between wheat and rye prices. Except under special circumstances, wheat prices were but slightly affected by the behavior of rye prices. In 1908-09, for example (Chart 5), the world market price of wheat rose from the preceding year by 10.9 per cent, while that of rye declined by 5.9 per cent.

In the next two charts, net imports and supplies of major

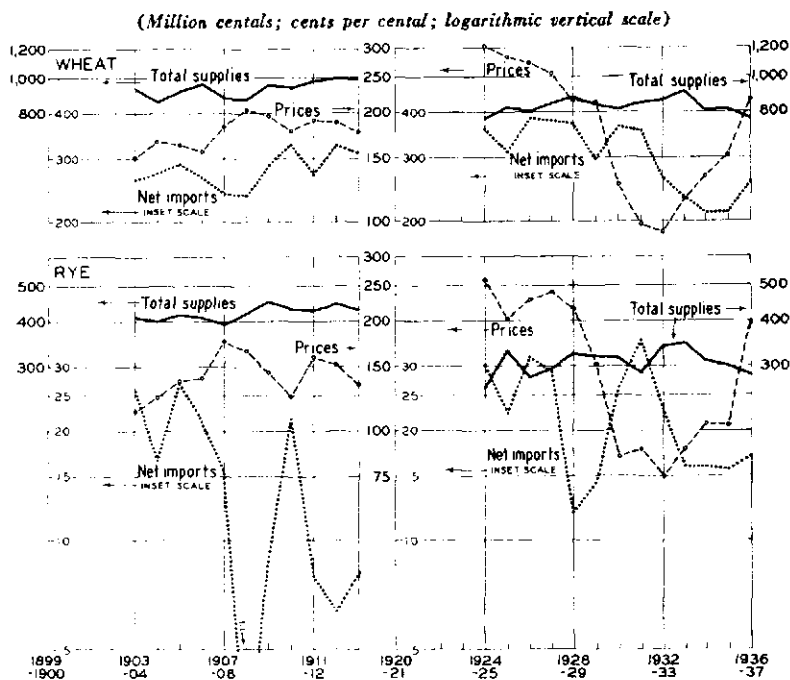
grain-importing countries of Europe for a number of years are compared with world market prices. Practically all imports of all grains here studied except wheat are normally absorbed by European countries, and these take also the bulk of wheat imports. Hence the supply situation in the European importing countries, in their aggregate, broadly reflects the supply situation in the world as a whole. Abundant total supplies in importing Europe, especially in conjunction with large net imports, are commonly accompanied by low world market prices, and vice versa. To get a complete picture, however, the supply situation in exporting countries has to be consulted occasionally. The impossibility of adjusting the data on total supplies for changes in year-end stocks detracts materially from their usefulness for our analysis.

The section devoted to wheat in Chart 7 suggests that wheat price changes in the last eleven prewar years can be explained mainly by the supply situation for wheat, and that consequently the supply or price situation in other grains could have had little effect on the wheat market.⁶ In these eleven years, year-to-year changes in prices and total supplies of wheat in European importing countries were in the same direction only twice, from 1909-10 to 1910-11 and from 1910-11 to 1911-12. In 1910-11 wheat prices declined by 8.8 per cent, in spite of a small decline (by 1.7 per cent) in total supplies. This decline was caused by the very small harvests in Italy and France, which seldom enlarged their net imports of wheat to the full extent of the deficiency in their own crops in poor years, or contracted their imports correspondingly in good years.⁷ Such wheat as France and Italy wished to import in 1910-11 was easily obtained at declin-

⁶Helen C. Farnsworth of the Food Research Institute, who is making a special study of year-to-year changes in the world wheat market in prewar years, believes that shortage of corn was a significant factor in world wheat markets in at least two earlier years, 1894-95 and 1901-02.

⁷Such behavior of France, Italy, and some minor countries was so pronounced that it was clearly reflected in data for importing Europe as a whole. The same phenomenon can also be observed in the postwar period, especially before the strict market regulations of recent years. See J. S. Davis, "The World Wheat Situation, 1936-37," *Wheat Studies*, December 1937, XIV, 179.

CHART 7.—NET IMPORTS AND SUPPLIES OF WHEAT AND RYE IN IMPORTANT DEFICIT EUROPEAN COUNTRIES, AND WORLD MARKET PRICES, BY YEARS, PREWAR AND POSTWAR*



* Data on net imports and on supplies (production plus net imports) are from Table VI. Prices are those used in Chart 5.

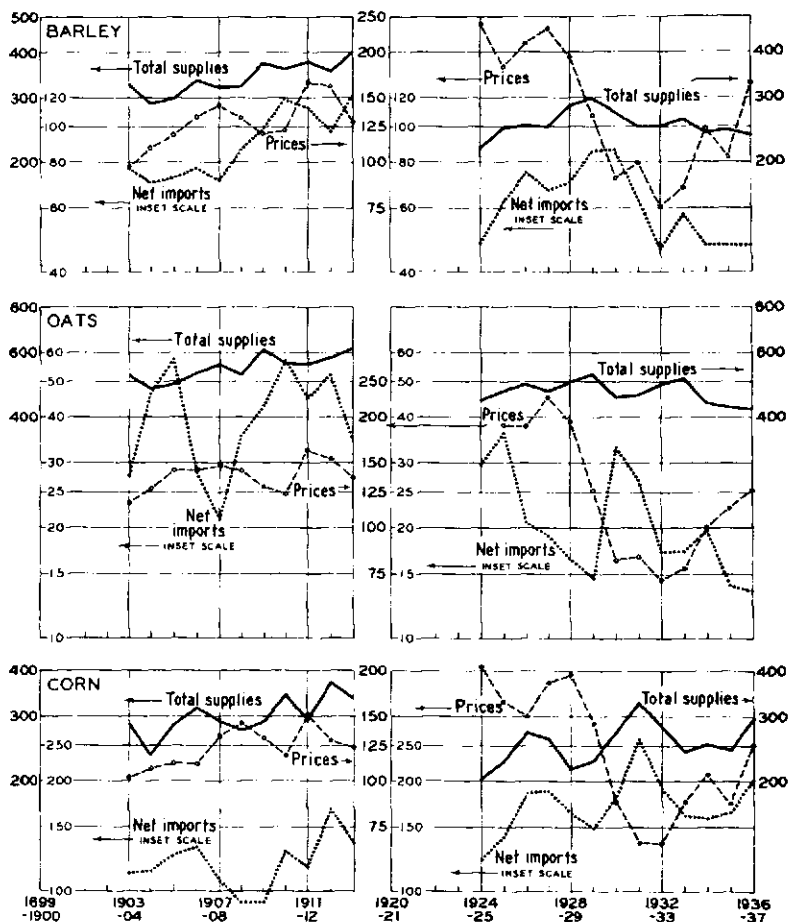
ing prices, caused by bumper crops in Rumania and British India and successive good crops in Russia.⁸ The situation in 1911-12 was the reverse of 1910-11; supplies increased by 4.4 per cent and prices too advanced by 6.9 per cent. Importing Europe needed only small supplies in addition to her own good crop, but these could be obtained only at very stiff prices because drought in eastern Russia greatly reduced the supplies in the main sources of exports.

The swings of grain prices—in fact, of all prices—in post-war years, caused by factors almost entirely outside the grain

⁸ The situation in world markets was particularly easy in the later months of the crop year when export wheat was obviously pressed on buyers.

CHART 8.—NET IMPORTS AND SUPPLIES OF BARLEY, OATS, AND CORN, AND WORLD MARKET PRICES, BY YEARS, PREWAR AND POSTWAR*

(Million cents; cents per cental; logarithmic vertical scale)



* See note to Chart 7.

market, were so wide that one's first impression of the right-hand section of Chart 5 is that all curves behave alike. Closer examination, however, suggests that within this general similarity wheat prices went their own way, frequently diverging from those of the other grains. With regard to the depend-

ence of the level of wheat prices on those of the other grains, in fact, no material difference between the behavior of prewar and postwar prices can be found. Prices of feed grains fell sharply in 1925-26, while wheat prices remained not very far from the high level attained in the previous year. The price of wheat was more than 80 per cent above that of corn in 1926-27 and only 11 per cent higher than the corn price in 1928-29. In 1935-36, the wheat price again exceeded that of corn by approximately 75 per cent.

For those postwar years when the supplies of wheat did not materially exceed the demand for food, the Food Research Institute generally succeeded in explaining each year's price developments in the world wheat market from the supply situation in this grain in surplus and deficit countries and from the general conditions of business, including the general price level. Except for China, the supply situation in other grains rarely had to be considered as a factor which might have affected the world import demand for and the prices of wheat.⁹

The world market price of wheat comes into close touch with prices of feed grains only when surpluses of wheat in exporting countries far exceed the demand for food in importing countries and the situation cannot be relieved unless substantial quantities of wheat are used for feed. Prices seldom fall to the extent that such use becomes possible, however, before the excess of wheat supplies over the demand for food¹⁰ has lasted for some time. For such prices are considered abnormal by everybody concerned; and sellers are reluctant to sell, whereas traders, processors, and consumers are inclined to increase their stocks beyond the usual size.

Even in such cases it has rarely if ever happened in the

⁹The Food Research Institute incidentally possesses a much more useful series for supplies of wheat in Europe ex-Russia ex-Danube in postwar years than that presented in Chart 7, with supplies adjusted for changes in year-end stocks. But this series could not be used in Chart 7, because no similar data are available for other grains.

¹⁰Including that portion of the use of wheat for feed which is used even if prices of fair wheat are substantially above prices of feed grain—unmillable wheat, wheat used in poultry mixtures in moderate amounts, wheat used on farms under the protection of double marketing costs (pp. 160-64), and the like.

history of the world trade that wheat of average quality was imported in substantial quantities for use as feed. World market prices for good milling wheat have perhaps never been so low. The contact between the markets for wheat and feed grains under conditions of excessive supplies of wheat is usually established in such a way that wheat of less desirable quality (as that of northwestern Europe) or located in places deficient in feed grains and having an excess of low-quality wheat (as in California) becomes as cheap as or cheaper than feed grain.

In the early 1890's, world market prices of wheat—probably for the first time—were occasionally not much higher than feed-grain prices. But in the fifteen latest prewar years the prices of imported red wheat at Liverpool always exceeded corn prices by at least 25 per cent, and the average difference was more than 40 per cent (Chart 5). In postwar years, wheat prices were only once almost as low as the prices of feed grains. Incidentally, that was a year when, despite superabundance of wheat supplies, wheat prices were not really low;¹¹ prices of feed grains were high owing to a shortage of supplies.

Wheat: substitution between classes and grades.—A large degree of adjustment—especially long-run adjustment—of consumption to the quality of the wheat produced locally can be observed. In some countries this adjustment goes so far that, if the locally grown type of wheat does not produce a good raised bread, the population continues to adhere to flatbread or alimentary pastes to a considerable extent. This seems to be particularly the case in some Mediterranean countries producing much durum wheat of mediocre quality. The large consumption of macaroni in Italy also may represent some such adjustment. Yet in several countries important for the formation of world market prices, the consumers of wheat bread and other products made of wheat insist on having the desired products in a definite form (bread

¹¹ Timoshenko, "Monetary Influences on Postwar Wheat Prices," *op. cit.*, pp. 276, 299. Corresponding data for 1938-39 were not available to the author.

of certain kinds, crackers, pastes, etc.) and of a definite quality, to such an extent that substitution of one type of wheat for another and of lower grades of certain kinds of wheat for higher grades of the same kind also is materially limited; and these limitations are reflected in the demand for specific types and grades of wheat that are particularly adapted to the production of specific products.

Macaroni and similar pastes are considered to be of good quality only if they are prepared of semolina, made from good durum wheat.¹² Such durum wheat has hard, vitreous, almost translucent kernels, and is very high in protein content. The yellowish (amber) color of the semolina and pastes produced from this durum has become the attribute of good macaroni to such an extent that color is added (unless prohibited by law) if other wheats are used in their preparation.¹³ Durum wheat therefore constitutes a separate market.¹⁴ It is cheaper than common wheat in one year and may command high premiums in the next. The left-hand section of Chart 9 shows clearly these ups and downs for the United States. The situation is similar in the world markets.

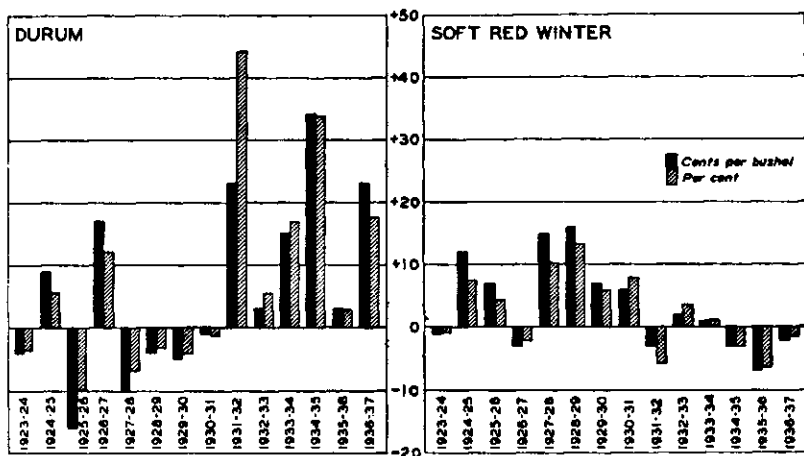
Separation of functions is not limited to that between common wheat and durum, but is also found for different types of common wheat. In some countries, notably the United States and Great Britain, large volume and fine texture are considered the most important properties of good bread, and common wheat with a fairly high content of protein of good quality is required to make it. Such wheats are rather hard and vitreous (except by comparison with good

¹² See C. L. Alsberg, "Durum Wheats and Their Utilization," *Wheat Studies*, April 1939, XV, 337-64. The discussion in the text does not cover alimentary pastes used in soups, for which the requirements are sometimes different.

¹³ Color is also used to give plain paste the appearance of a product made with eggs.

¹⁴ In the United States, probably even the admixture of red durum to amber durum does not occur. In Italy, the motherland of modern macaroni, no wheat other than durum was probably used in macaroni preparation, prior to the restrictions on imports imposed in recent years; but much poor durum grown in Italy or other Mediterranean countries was employed in the production of cheaper grades. In Germany some pastes were prepared entirely of common wheat even before the import restrictions of recent years. All the pastes in China and Japan are made from common wheat; some in China also of sorghum, alone or mixed with common wheat.

CHART 9.—SPREADS OF PRICES OF SOFT RED WHEAT AND DURUM WHEAT FROM AVERAGE PRICES OF ALL WHEAT EAST OF THE ROCKIES IN THE UNITED STATES, ANNUALLY, 1923-24 TO 1936-37*



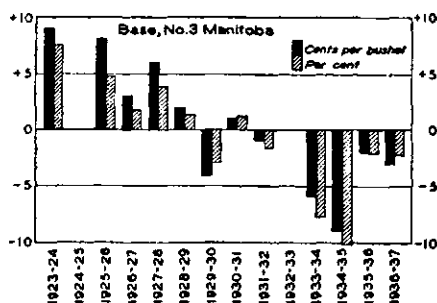
* Based on data in *Wheat Studies*, December 1937, XIV, 180. Prices of No. 2 Red Winter in St. Louis and of No. 2 Amber Durum in Minneapolis, compared with averages of prices of No. 1 Dark Northern Spring and No. 2 Amber Durum at Minneapolis, No. 2 Hard Winter in Kansas City, and No. 2 Red Winter in St. Louis, weighted by production of each class. (From 1934-35, the durum grade is called No. 2 Hard Amber.)

durum wheats) and usually of red color. They are called strong wheats. The slightly yellowish color of bread produced from strong wheat is sometimes regarded as an attribute of good bread, but in most cases it is eliminated by bleaching. Strong wheats sell at substantial premiums unless offered in very large quantities.

Some consumers want bread as white as possible (the color of bleached flour from strong wheat is white but with a slight grayish hue) or lay stress on flavor, but are less particular with regard to volume and texture. This is the case, for example, in Italy and especially in Ireland.¹⁵ White wheat with a fair content of protein of fair quality is best suited for this purpose. White wheats also are preferred for cookies, cakes, and similar products. When the proportion of the supply of white wheat to total supplies in the world markets is

¹⁵ Biscuits for which such wheat is desired are bread in the sense of our definition.

CHART 10.—PRICE SPREADS BETWEEN AUSTRALIAN AND No. 3 MANITOBA WHEATS IN THE UNITED KINGDOM, ANNUALLY, 1923-24 TO 1936-37*



* Based on data in *Wheat Studies*, December 1937, XIV, 181.

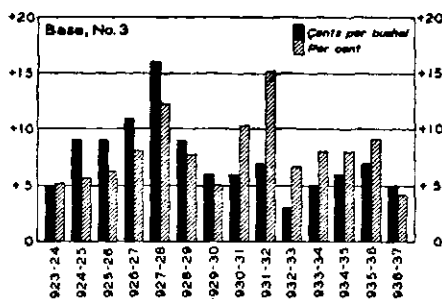
barely sufficient to cover the specific demand for it, good white wheat may sell for more than strong red wheat, and vice versa. Chart 10 shows that Australian, an average grade of a good white wheat, for years was persistently above No. 3 Manitoba, an average grade of the strongest wheat in the world. With an increase of the proportion of white wheat in total world wheat imports to Europe since predepression years, Australian wheat has been persistently cheaper than No. 3 Manitoba.¹⁶

In the eastern United States, soft red winter wheat rather than white wheat is typically used for all purposes where strength of flour is not important, as in self-rising flour for biscuits, and flour for cookies, cakes, and the like. The fact that prices of soft red winter vary materially relative to the general level of wheat prices (right-hand section of Chart 9) indicates that the degree of substitution is not very large in this case also, in spite of the availability of large quantities of wheat intermediate between hard and soft which facilitates substitution.

Finally, in such markets as the United States, a high degree

¹⁶ This change may also be partly due to an increased evaluation of hard wheats. Working's analysis for the period 1921-22 to 1936-37 showed that "in recent years importers have been willing to pay higher premiums than formerly for hard wheats when the supplies of such wheat have been relatively small." See Holbrook Working, "Price Effects of Canadian Wheat Marketing," *Wheat Studies*, October 1937, XIV, 43.

CHART 11.—PRICE SPREADS BETWEEN NO. 1 AND NO. 3 MANITOBA WHEATS IN WINNIPEG, ANNUALLY, 1923-24 TO 1936-37*



* Based on data in *Wheat Studies*, December 1937, XIV, 180.

of resistance to substitution is shown even as regards wheats of the same type. The milling industry that produces bread flours makes strenuous efforts to keep the percentage of protein in its flour the same from year to year, in spite of year-to-year changes in the composition of the crop. Hence high-protein wheats command large premiums over similar wheats with an average protein content in years when the average protein content of the bread wheats is low (8 cents per bushel was paid for each additional per cent of protein in 1928-29) and sell for about the same price in years when the crop averages high in protein content.¹⁷ Not quite so marked are the variations in the prices of strong wheats in the world markets. Yet No. 1 Manitoba, the best of the strongest wheats in the world, is sold at a premium of 5-7 cents over No. 3 Manitoba, still a good strong wheat, in years when the Canadian wheat crop is of high average quality. In 1927-28, a year of poor-quality crop, the premium averaged 16 cents (Chart 11); in 1937-38, when supplies of the best hard wheats were extremely short, the average spread was 18 cents. Occasionally, as in 1937-38, monthly averages show premiums as high as 25 cents per bushel and more.¹⁸

¹⁷ See also C. L. Alsberg, "Protein Content: A Neglected Factor in Wheat Grades," *Wheat Studies*, February 1926, II, 163-76.

¹⁸ J. S. Davis, "The World Wheat Situation, 1937-38," *Wheat Studies*, December 1938, XV, 256.

All the wheats mentioned in connection with breadmaking are common wheats (*triticum vulgare*). Club wheats extensively grown in the Pacific States make poor bread but are adapted to biscuits, crackers, and the like. Durum wheat in general is not considered an adequate substitute for common wheat in breadmaking. But Russia, the largest producer of durum wheat in the world, presents a picture quite of its own. Flours milled from specific types of durum wheat (alone, or more often mixed with common wheat) are regarded as the best material for breadmaking. Before the World War, prices of suitable durum qualities were much above prices of the best common wheats. Millers used to buy their grist exclusively by sample, paying high premiums for good "color." Durums were even classified by the trade as those with and without color. Only the durums not wanted by domestic millers were exported. We are unable to ascertain what changes have occurred since the revolution, but officially fixed prices are regularly higher on durum than on common wheat.

The great variability in properties of durum wheat of different varieties and as grown under different conditions is one of the reasons for the striking divergence. The difficulty of properly handling durum wheat in the mill is another. But habits of consumers, and perhaps even more, adherence to specific milling and baking practices, probably have something to do with the preference for durum bread in Russia. This is slightly sweeter than bread made of common wheat, but the difference in sweetness could be perhaps made up by addition of sugar. Bread from durum is superior in flavor and durum flour has a higher water-retention power, but the bread is not as light. Even pretentious Russian consumers could perhaps be more easily satisfied with bread made from good common wheats, if they always were properly milled and baked.¹⁹ On the other hand, outside of Russia the blending of suitable durum wheats in preparation of flour for

¹⁹ See N. Jasny, "Der russische Weizen," *Landwirtschaftliche Jahrbücher*, 1926, LXIII, 411-61; also C. L. Alsberg, "Durum Wheats and Their Utilization," *op. cit.*

breadmaking may gradually come more into favor. The flavor of properly prepared durum bread might prove the attraction to consumers looked for by those apprehensive over the declining bread consumption.²⁰

Rye.—Past developments leave no doubt that in the long run wheat bread is an entirely adequate substitute for rye bread, save as a specialty. In the short run, however, both elasticity of the demand for rye used in breadmaking and the scope for substitution of other grains for rye in this use also seem to be extremely limited, though possibly not quite so limited as in the case of wheat. Rye bread is usually so much cheaper than wheat bread, in countries with a large consumption of rye bread, that the price differential in favor of rye bread remains large even when there is a substantial decline in the spread between rye and wheat prices. Moreover, rye bread remains cheaper when rye prices exceed wheat prices.²¹

Admixture of wheat flour into rye bread, and changes in the proportions of rye and wheat flour in the preparation of mixed bread, may constitute a more important form of response to changes in the relation between wheat and rye prices than shifts from rye to wheat bread or vice versa. But even such substitution is hardly ever large.

Low-grade wheat flour is used in the preparation of mixed rye-wheat flour. The price of this flour tends to be approximately the same as that of rye flour, even with wheat much more expensive than rye. Thus not very strong relative changes in wheat and rye prices *accompanied* by corresponding changes in the prices of flours may cause one of the ingredients of the mixed bread to become more expensive and to make advisable a change in the flour mixture. But the

²⁰ It should be therefore regretted that in the United States and Canada the attention of students seems to be confined to the adaptability of durum wheats to alimentary pastes.

²¹ See pp. 45-46. This is true even though in such countries the price of rye constitutes a considerably higher percentage of the price of rye bread than is the case with wheat and wheat bread, and that, consequently, the prices of rye bread are substantially more affected by changes in rye prices than the prices of wheat bread are affected by changes in wheat prices.

extent of such shift is limited to what customers will not object to, and sometimes also by considerations of baking technique. Moreover, where mixed rye-wheat bread is the only or the principal outlet for low-grade wheat flour, the price of this does not perforce follow the changes in wheat prices; the extra cost of, or the saving on, wheat may be primarily reflected in the cost of higher grades of wheat flour.²²

The great inelasticity of the demand for rye in the use as food, the limited substitution of other grains for rye or rye for other grains in this use, and the fact that rye ranks low as feed, cause rye prices to change widely in relative position. When the quantity of rye demanded for food purposes (plus the use for feed that does not significantly affect prices²³) is barely covered, rye prices tend to be substantially above the prices of feed grains. Scarcity of rye occasionally brings rye prices up to the level of wheat prices, and more frequently to the level of prices of the cheaper types of wheat. When supplies of rye are abundant, rye is merged into the group of feed grains, with a tendency to touch the bottom prices of feed grains or to fall even lower.

As stated, a coefficient of elasticity of demand computed from data on total production of rye adjusted merely for exports has very limited value. It may be noteworthy, nevertheless, that the coefficients of elasticity of demand for rye in the United States, as computed by Henry Schultz from such data for prewar years, were much lower than for either corn or oats and higher only than those of wheat and barley.²⁴

Timoshenko, in his study of wheat prices on the world markets covering approximately thirty prewar years, reached the conclusion that "rye is not a factor influencing fluctuations in the imports of wheat." "The population in western Europe does not shift from rye to wheat consumption, or vice versa, under the influence of short-time changes in the pro-

²² The same is even more true of millfeed.

²³ Use of farm-grown rye under the protection of double marketing costs, especially by self-sufficient farmers.

²⁴ Henry Schultz, *op. cit.*, pp. 548-49.

duction of either crop."²⁵ The fact that Timoshenko failed to discover an effect of the size of rye production in western Europe on wheat imports may have been due to the character of the statistics that he had; the data available on wheat for prewar years did not permit segregation of minor effects. Timoshenko's analysis also did not disclose the effect of the variations in the quality of the western European wheat crop on import requirements, although such effect hardly could have failed to be present. Moreover, Helen C. Farnsworth of the Food Research Institute believes that data for Germany for those years show that the demand for wheat depended somewhat upon the size of the rye crop. This very uncertainty is sufficient proof that the mutual substitution of wheat and rye in European import markets, if any, was only slight.

The data in Charts 5 and 6 (pp. 86 and 87) demonstrate, in fact, a large degree of independence of rye prices from prices of other grains. In 1907-08 the price of Russian rye in Bremen, Germany, was only 4 per cent lower than the price of red wheat of fair quality in Liverpool and was 24 per cent higher than the average prices of the feed grains in corresponding positions. The shortage of rye was removed in 1909-10. In 1910-11 the rye price was less than the wheat price by 31 per cent and exceeded the average price of the three feed grains by only 2.3 per cent. German rye in that year was obtainable in importing countries for materially less than imported feed barley or oats.

Changes in world rye prices in the eleven last prewar years can in general be explained by changes in total supplies and net imports of this grain in the major European importing countries (Chart 7, p. 90). In 1905-06, it is true, total supplies, imports, and prices of rye rose simultaneously; but this fact may have its explanation in the insecurity with regard to obtaining supplies owing to the first Russian revolution. Moreover, effective March 1 of that year the import

²⁵ V. P. Timoshenko, *Wheat Prices and the World Wheat Market* (Cornell Agr. Exp. Sta. Memoir 118, December 1928), pp. 50-51.

duty in Germany was increased from 3 to 5 marks per 100 kilograms. The expectation of a price rise in Germany after the new duties became effective brought it about that before March 1 her imports were larger and her exports less than in proportion to her 1905 crop; this situation could not fail markedly to boost the price of Russian rye used in Chart 5. The price declines in the face of a slight contraction of total supplies in 1910-11 and 1913-14 are sufficiently explained by the pressure of export supplies from Russia.

Extreme shortages of rye occurred repeatedly during the World War and in the early postwar years. At Chicago, the average price of rye was above the price of wheat in 1917-18 and again in April and July 1921. More frequently in those years, import countries could buy certain imported wheats other than American for less money than rye. The relative level of world market prices remained favorable for rye up to about 1928-29, though not without setbacks. Thereafter, and for several years, large supplies kept prices on a feed basis.²⁶ The shortage of export supplies of rye in 1936-37, in the face of small domestic production in western Europe, again temporarily brought rye prices near to wheat prices. Thus, during and after the war, prices of rye were mainly determined by its specific supply situation.

Since rye has to satisfy the demand only for common bread that is consumed because it is cheap, there is little room for price differentials between different *types* of rye. Rye produced in continental climates is preferred for breadmaking, but the premiums paid are seldom more than a few per cent of the price, particularly if prices are calculated on a dry-matter basis (Chart 16, p. 125).

²⁶ The prices of imported rye on the world markets used in Chart 5 (p. 86), do not show the full extent to which rye prices have fallen in recent years. Prices of domestic rye in European countries, except where artificially held up by protection, demonstrate this development clearly (Chart 2, p. 10). In the United States (Chart 6, p. 87) rye was cheaper than oats in 1930-31 by approximately 25 per cent and cheaper than corn by 39 per cent. A price disadvantage of such magnitude reflects an almost definite refusal to use the excessive rye for feed purposes, price inducements notwithstanding. Such an extreme situation, it is true, could probably occur only in the United States, where most feeders are unfamiliar with the use of rye for feed and can more easily afford not to bother with less desirable feeds.

The price differences between different *grades* of rye of the same types are small partly because of botanical characteristics of the rye plant; its sturdiness successfully resists damage to the grain. Other reasons are the absence of demand for high grades of rye flour and the small price spread between rye flour and rye feed as compared with that between wheat flour and wheat feed. It is characteristic of the botanical properties of rye, and of the demand that rye must satisfy, that in all important North American markets, Winnipeg, Minneapolis, and Duluth, the average quotations are usually the same for No. 1 and No. 2 rye.

Grains used for flatbread and porridge.—The situation with regard to the substitution of different grains in the use for flatbread, porridge, other breakfast preparations, and the like, in general does not differ much from that of the bread grains. In many instances the demand is specialized no less than that for bread. Rolled oats, for example, are the only breakfast cereal of importance in Great Britain, some other countries in northern Europe, and Canada; thus there is no way for substitution other than by the especially resisted shift to other types of food. So far as concerns countries with a high standard of living, the demand for buckwheat for food in the United States may perhaps represent an exception, because the proportion of buckwheat flour in mixed pancake flour may be altered rather easily. This may be the explanation for the relatively high coefficients of elasticity of demand for buckwheat (-1.28 ± 0.24 in 1879–95 and -0.69 in 1896–1914) computed by Schultz.²⁷

There is somewhat more room for changes in the proportions of flour used in the preparation of mixed corn-wheat bread²⁸ in response to price shifts. Moreover, since corn preparations are used in competition with wheat almost exclusively by poor populations, and primarily owing to their cheapness, large price advances in corn probably cause some

²⁷ Henry Schultz, *op. cit.*, p. 549.

²⁸ Mixed corn-wheat bread is mostly made with some raising agent; hence it might have been discussed at an earlier point.

substitution of wheat for corn other than through the proportion of corn in corn-wheat bread.²⁸

In such countries as Russia, where two grains are used for kasha, the extent of mutual substitution of the two grains used in its preparation (buckwheat and millet) may be even larger than the substitution for corn. Yet even there material price changes are probably needed to induce relatively moderate shifts from one type of kasha to another. Large shifts such as have become necessary in post-revolution years²⁹ are vigorously objected to, in spite of a food situation equivalent to or approaching real starvation.

Substitution seems to be large in materials used in the preparation of flatbread in India. Several coarse grains and also gram, a dry legume, are involved in this mutual substitution more than is wheat. It is difficult to get an idea about substitution in the use for porridge and flatbread of one *type* or *grade* of corn for another, because the specific requirements of consumers are in general limited to the color of corn, and such preferences are easily satisfied by producers. In the southern United States, white corn is preferred for hominy, cornmeal, and similar products, whereas in the north the yellow color is preferred; both sell at a premium over mixed corn.³⁰ Egypt agrees with the South and Bulgaria with the North in this regard. In some Danubian regions, Cinquantino and similar small-kerneled, hard, high-protein, early varieties of yellow flint corn, which are not as prolific as later-maturing varieties, seem quite regularly to command high premiums.

²⁸ In "World Wheat Survey and Outlook, May 1938" (*Wheat Studies*, May 1938, XIV, 324), for example, H. C. Farnsworth and Holbrook Working state that "a second successive good wheat crop and a poor harvest of corn appear to have been important in raising Rumanian wheat consumption above the low level characteristic of the three preceding years."

²⁹ The ratio between the supplies of buckwheat and millet has greatly increased in favor of millet. Yet buckwheat groats are the more desirable of the two, or, with many consumers, the proportion of buckwheat kasha desired is much larger than that of millet kasha.

³⁰ Information from E. G. Boerner, Senior Marketing Specialist, Bureau of Agricultural Economics, U.S. Department of Agriculture. On uses of corn in the United States generally, see C. L. P. Corbett and E. G. Boerner, *Uses and Products Made of Corn, Abstracts and References* (U.S. Dept. Agr., Bureau Agr. Econ., mimeographed publication, March 1937).

The price differentials between different grades of wheat and rye used in flour production are larger than would correspond merely to the difference in the amount of flour and feed which can be extracted from them, for the flour from grain containing less of it averages lower in quality. Such considerations are of particular import in the use of hulled grains, barley and oats, for production of groats and flour. Goods of high quality probably cannot be produced at all from lower types and grades of barley and oats. The differences in the extraction percentages are large in any case, and the processing of poorer grain may cost materially more. All in all, the premiums for better types and grades of the hulled grains used in the preparation of food products are likely to exceed those justified by the lesser content of hulls, by a greater margin than is true of wheat and especially of rye. Premiums for desirable qualities of barley and oats may therefore be relatively large even where no shortage of them exists. One would expect especially high premiums for naked barleys where, as for example in Japan, barleys are used for food without processing by modern machinery.⁸¹ But the fact that barleys in such form are eaten only by very poor populations apparently prevents large premiums from developing.

IN BEER PREPARATION

The price of grain used in beer preparation is unlikely to affect appreciably the consumption of beer and the demand for malting grain. Furthermore, no grain other than barley is used in substantial quantities in the preparation of beer. The problem of demand elasticity for malting grain is therefore in the main reduced to the problem of the extent of replacement of barleys which are expected to produce better beer by barleys believed to be less suitable for the same purpose. Such substitution is made very reluctantly, and hence the price spreads between malting barleys of different quality tend to be very large.

⁸¹ See C. L. Alsberg, "Japanese Self-Sufficiency in Wheat," *op. cit.*, p. 78.

On October 13, 1937, *Broomhall's Corn Trade News* reported on the market situation in English barley during the preceding week: "A good trade has been reported in English malting barley, best samples being in demand at around 70 shillings per 448 pounds. Medium to good qualities were dealt within a price range of 45 to 65 shillings." Thus the best malting barleys were worth 50 per cent more than malting barleys of lower grades. In this country the usual range of the prices of malting barley is even larger. On March 30, 1938, malting barley at Minneapolis was quoted in cents per bushel of 48 pounds, as follows:

Choice	80-82
Medium grade 44-45 lb.	56-78
Medium grade 42-43 lb.	50-65
Low grade	46-55

Thus the highest price exceeded the lowest by about 75 per cent. At the same date and at the same market the range of wheat prices was equivalent to 26 per cent and the range for rye prices actually paid was only 4.5 per cent.³²

From year to year the idea of what is malting barley of suitable quality changes greatly, it is true. When the barley crop happens to be of poor quality, beer is made of barley that in other years would be refused indignantly. But in such years the selection of slightly more adequate samples proceeds with special care, and the price spreads become particularly wide.

IN FEED USE

Little statistical analysis of the demand for feed grains has been made. Schultz's analysis shows that the demand for corn and oats in the United States, though inelastic, is considerably less inelastic than that of food grains. This can be accepted for other countries and for the world market as a

³² The above data for wheat and barley are from the official closing price quotations; for rye the range is that of actual sales. The date was picked at random but may be regarded as rather typical except of years in which large premiums are paid for wheat with a high protein content. The week for which the information on the English market was given was also an ordinary week.

whole. But the larger elasticity of demand for each feed grain is caused by greater changes in demand in response to price both without and with substitution of one feed grain for another. Though definite conclusions on the elasticity of demand for feed grain cannot be reached without considering the changes in demand without substitution, the following discussion must be limited primarily to substitution.

Analysis of the use of grains for feed has shown that from the scientific viewpoint there are wide possibilities for substitution of one feed grain for another, in spite of differences in the adaptability of individual grains to specific requirements of different animals. Corn can be substituted for all other grains, except where there is objection to the quality of pork and bacon from hogs fed corn, or perhaps for working horses at great speed or in very hot climates. Even in these cases, objection is directed mainly to making up the whole grain ration of corn. Oats can be used successfully for all kinds of animals except as the principal feed of hogs in the finishing stage. The possibility of substituting other grains for corn or oats and for each other is more limited but is large nevertheless. The use of barley is less indicated as the principal grain for working animals. Wheat seems useful for all kinds of animals, but is recommended for use as part of the grain ration only. The largest limitations are those met with in the feeding of rye. Yet experience in Germany and some other countries shows clearly that large amounts of rye can, without great difficulty, be used as feed in place of any other feed grain, although not for all kinds of animals.

So far as limitations in the use of certain grains for definite purposes are encountered, wide adjustment can be reached by circular substitution, mixing, or both. In case of a deficit in oats, for example, corn can be substituted for oats as a horse feed, while the ensuing deficit in corn can be met by feeding more barley to hogs. Mixing of different grains is persistently gaining in favor with experts and feeders. It is a firmly established practice in feeding poultry, but gains

ground also as to other animals; it may become general wherever feeders purchase their feed grains in markets conveniently supplied with different grains.

Moreover, the different grains do not diverge much in content of nutrients. Hence it could be expected that prices of different feed grains would not be far apart, even though the proportion of each grain in the total supplies of feed grains varies greatly from region to region and is always changing. Analyses of prices and other data, however, show that this expectation does not materialize fully even in the long run. Considerable disparities between the prices of different feed grains, not justified by their feed value, last for decades. Smaller disparities, indeed, seem to be almost permanent. In the short run, prices of each feed grain rarely fail to participate in major changes in the price level of feed grain. Short-run variations in ratios between prices of different grains, caused by variations in the proportions of each feed grain to the total supply, are nevertheless considerable and sometimes even violent. Except in years of large changes in the price level of feed grain, the changes in supplies of each feed grain commonly appear to be the predominant factor determining the price changes of that grain; but more statistical analysis than is available would be desirable to arrive at more definite conclusions.

Two main reasons can be brought forward in partial explanation of the failure of the prices commonly used in the analyses to reflect strongly the technical possibilities of substitution of one grain for another. One, a real reason, is that the advantages of substitution are not fully realized by feeders; the second that the opportunities and advantages of substitution are less than those indicated by the prices commonly used in such comparisons. Food grain is processed in large establishments, but almost every one of millions of farmers is also a feeder. An immense amount of ingenuity is exerted by the processors of food grains in substituting one type, class, or grade of grain for another, without changing the

quality of the finished product. Farmers cannot be expected to be equally alert and informed, whereas owners of city horses and especially the army are even more reluctant to substitute any other grain for oats. Generations are frequently insufficient to overcome the inertia, stubbornness, or ignorance of the great number of feeders. As we have seen (pp. 54-66), prejudices with regard to the feeding value of different grains for different purposes are carried into textbooks, and experts in different countries give divergent advice.

The prices most frequently used in statistical analysis are prices in large central markets, i.e., not the prices to the feeders. (Farm prices, even if available, seem to have some disadvantages of their own.) The ratios between prices paid by many feeders usually are less favorable for substitution than the price ratios in large favorably located markets. Most feeders, moreover, produce rather than buy their own feeds. The substitution of a purchased feed for one grown on the farm involves double marketing costs, which frequently wipe out very large price differentials or even reverse the price relation. Distance, an important factor in explaining differences in consumption of food grains, is an even much more important obstacle to the attainment of the technically possible degree of substitution among feed grains (see chapter vi).

The world market.—Average prices of all three feed grains on the world markets tend to be rather close together. This is particularly true of feed barley and oats; the prices of these grains are so close that they change their places from one period to another (Chart 3, p. 11). Corn has been persistently cheaper than the other two feed grains, but the difference as compared with the price of the next cheapest feed grain has not been large. This similarity, however, is not revealed in individual years; on the contrary, occasionally the prices are even far apart (Chart 5, p. 86). In 1900-01, the uncorrected price of oats³³ exceeded that of corn by as much as 35 per cent. The price difference between the same

³³ See footnote 13, p. 79.

grains was large (28 to 30 per cent) and in the same direction also in 1899-1900, 1901-02, 1905-06, and 1906-07. The prewar world market prices of feed barley in general were closer to those of corn, but in 1912-13 exceeded them by 25 per cent. Substantial disparities between the prices of feed barley and corn also occurred in 1900-01 and 1906-07, when barley was more expensive than corn by 18 and 19 per cent, respectively.

Data on total supplies and net imports of major European importing countries in prewar years in Chart 8 show that in most cases no disparities can be found between the price situation for each feed grain and its specific supply situation. Only in two prewar years, for example, were the changes in prices of corn not in the opposite direction to the changes in total supplies. One of these was 1905-06, when prices of all feed grains and of rye advanced in the face of increasing supplies. In 1913-14 corn prices fell in spite of the smaller total supplies and net imports, undoubtedly as a reaction to the plentiful supply of other grains. In all other prewar years, the changes in prices and total supplies of corn were in opposite directions.

This of course does not exclude effects of more moderate nature from the side of other grains on the corn market. On the contrary, such effects as accelerated price advances or declines owing to scarcity or abundance of other feed grains undoubtedly occurred, though they are not always easily proved.

The major discrepancies between the prewar supplies and prices of barley can in general be explained without reference to other markets. For example, the price of feed barley advanced greatly from 1910-11 to 1911-12, while barley imports were reduced only moderately and total supplies of barley (trend considered) even increased slightly. The contraction of net imports and total supplies of corn might have had something to do with this increase. In the next year, barley prices declined although net imports were reduced more than in the preceding year and total supplies were reduced

materially. This time, the fall in barley prices might have been in sympathy with a similar decline of oats and corn prices. But the major causes of the variations in the prices of feed barley in those two years probably were the effects, not of the markets for other grains, but of the Balkan War, which threatened to cut off the import markets from southern Russia and Rumania, the principal sources of exports of feed barley, and of the changes in hog numbers in important countries that relied heavily on imports for their supplies of hog feed.

The dependence of the prices of oats on their specific supply situation seems to have been even greater than in the case of corn and barley. If this is true, it was hardly accidental, in our opinion, but has correctly reflected the greater reluctance of feeders to substitute corn or barley for oats than corn for barley, or vice versa. The difference in the degree of mutual substitution of corn and barley as compared with that of oats and the other two feed grains was even larger than is indicated by data in Charts 5 and 8. In the last eight prewar years, the differences between corn and barley prices in the world markets would have been less than they actually were—both in averages of several years and in individual years—except for the privileged treatment of feed barley by the German tariff.⁵⁴ In those years also, barley and corn prices would probably have shown somewhat more interdependence in their year-to-year changes, if the low import duty on barley had not greatly impeded the access of corn surpluses to the German market.

In postwar years (right-hand section of Chart 5) the discrepancies between the yearly prices of the feed grains have been even greater than in prewar years. Oats prices varied from 88 per cent of the price of corn (1929-30) to 130 per cent (1935-36). The range of prices of feed barley in terms of corn prices was from 93 (1929-30) to 147 per cent (1931-32).⁵⁵ As is true of prewar years, the data in

⁵⁴ From March 1, 1906, the conventional import duty on corn was 30 German marks per metric ton and that on feed barley only 13.

⁵⁵ In 1931-32 feed barley was slightly more expensive than wheat.

Charts 5 and 8 lead one to infer that the coincidence between the year-to-year changes of the world market prices of different feed grains, so far as it was not caused by such general factors as money, was to a considerable extent due to concurrent changes in supplies of the same grains. Only the lesser part of the price changes of such feed grain may have been caused by the mutual substitution of one feed grain for another. The effect of substitution on these prices in general seems to have consisted in moderating or strengthening the swings caused by changes in supplies of that grain.³⁶ So far as interdependence between supplies and prices of different grains can be traced, it seems to have been larger between corn and barley than between oats and the other two feed grains.

The United Kingdom.—To illuminate the situation in the European importing countries somewhat further, in Chart 12 are compared the prices and supplies of corn in the United Kingdom in twelve prewar and twelve postwar years, the proportions of supplies of corn to the total supply of the major feed grains (barley, oats, and corn), and the ratios between corn prices and the simple average prices of the major feed grains. The curve for price ratios shows a considerable degree of inverse correlation with the curve of the supply ratios. But this fact, taken by itself, evidently does not testify in favor of a large amount of substitution of one feed grain for another. The same situation would have occurred if the comparison had been made between the prices and supplies of two non-competing goods, for example cotton and coal, provided that the price of each was negatively correlated with its supply.³⁷

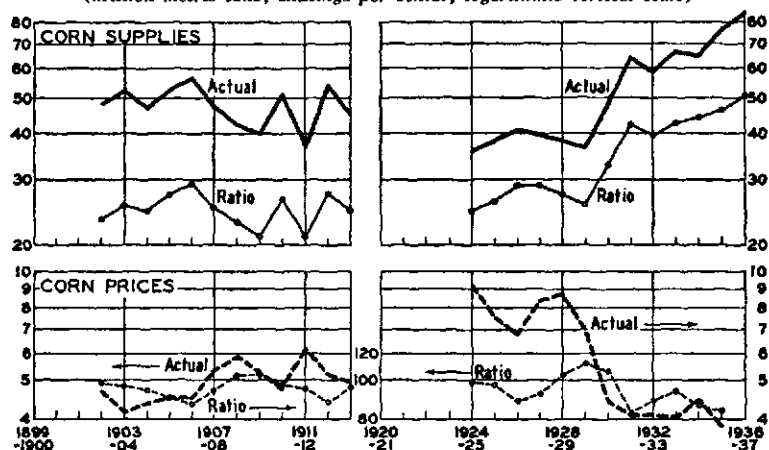
Inspection of Chart 12 shows that inverse correlation between the price ratios and the supply ratios is caused by a similar correlation between the prices of corn and the sup-

³⁶ The greater divergences between the prices of different feed grains in postwar years as compared with prewar years may have been due to the increase in the year-to-year variations in world exports of different feed grains.

³⁷ Strictly, it is not even essential that the price of each be negatively correlated with its supply. High negative correlation between the ratios may be obtained even though the price of only one of the goods is negatively correlated with its supply, provided the variability of price and supply of the other good be relatively small.

CHART 12.—SUPPLIES AND PRICES OF CORN, AND THEIR RATIOS TO THOSE OF MAJOR FEED GRAINS, IN THE UNITED KINGDOM, BY YEARS, PREWAR AND POSTWAR*

(Million metric tons; shillings per cental; logarithmic vertical scale)



* Supplies: prewar, net imports; postwar, imports. Prices: prewar as used in Chart 5; postwar prices of typical feed grades (Russian or Danubian barley, Canadian feed oats, Argentine corn) at English ports. Supply ratios: percentages of corn imports (prewar, net imports) to domestic production of barley and oats plus imports (prewar, net imports) of barley, oats, and corn. Price ratios: percentages of corn prices to the average of prices of barley, oats, and corn.

plies of that grain. In nine out of twelve prewar years considered in the chart, changes in prices and supplies of corn have been in the opposite directions; this was not the case only in 1905-06, 1909-10, and 1913-14. In 1905-06, corn supplies increased by 10 per cent despite a slight advance in corn prices by 4 per cent. As already mentioned, this was a year when all prices of feed grains rose simultaneously with an increase in total supplies. In 1909-10, a year when a period of general scarcity of grain was relieved and all grain prices went down, corn prices fell in the face of declining supplies of corn. The ratio of corn supplies to total supplies of feed grain declined even more and the ratio of corn prices to prices of feed grain improved slightly. The situation was similar in 1913-14, when corn imports were contracted by 19 per cent and the supply ratio declined by 10 per cent in the face of a decline in corn prices by 5 per cent. The easiness in the feed-grain market that brought about this abnormal

price development was reflected in the increase of the price ratio by 8 per cent. Influences of other grains on the corn market, of a less strongly modifying nature, may have occurred in other years.

The situation on the British market in postwar years was approximately similar to that in prewar years: most changes in corn prices coincided with changes in supplies of corn, in the opposite direction. The market for corn seems clearly to have been affected by the markets for other feed grains in 1924-25 through 1926-27. Prices of corn fell by 27 per cent, but imports increased by only 14 per cent from 1924-25 to 1926-27. The fall of corn prices in those years seems to have been strengthened by the fact that the prices of the other feed grains declined in the same two years by 12 per cent (oats) and 13 per cent (barley). Another example of the effect of other feed grains on the corn market is perhaps afforded by 1934-35, when corn prices advanced by 12 per cent while imports declined only by 2 per cent. For barley prices increased by 29 per cent in that year; but 1934-35 was a year of general economic recovery, and this may have contributed to the advance of the corn price.

Germany.—Practically all of the barley imported into Germany is used for hogs. A large portion of the imported corn also was so used until recently. Moreover, much of the imported corn and barley was fed in a relatively small area in the neighborhood of the ports of Hamburg and Bremen, and largely by feeders whose own production of feed barley was negligible. Thus there was *direct competition between barley and corn under equal marketing costs* from the harbors to feeders for both grains. We are therefore inclined to assign more importance to the comparison in Chart 13 than to that for the United Kingdom. Another reason for analyzing the situation in a second country is that the English market is especially particular with regard to its requirements as to the quality of hogs, and that the temperament of the British seems not to favor frequent changes of any kind.

The factors compared in Chart 13 are net imports and

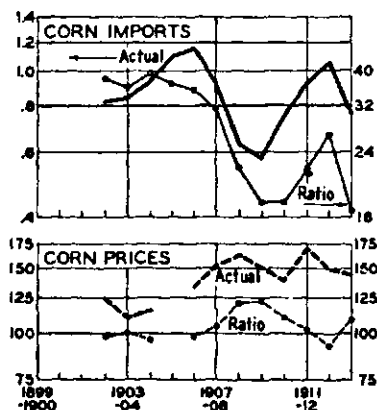


CHART 13.—NET IMPORTS AND PRICES OF CORN, RATIOS OF NET IMPORTS OF CORN TO THOSE OF BARLEY, AND RATIOS OF CORN PRICES TO BARLEY PRICES, IN GERMANY, ANNUALLY, 1902-03 TO 1913-14*

(Million metric tons; marks per metric ton; logarithmic vertical scale)

* Prices as in Chart 5 plus import duties as follows per metric ton: 1902-03 to 1904-05, corn 16 marks and barley 20 marks; from 1906-07, corn 30 marks and barley 13 marks. Prices and price ratios for 1905-06 are not shown, since import duties were changed in that year.

prices of corn in Germany, ratios of net imports of corn to those of barley and corn, and ratios of corn prices to barley prices. The data are for the same twelve prewar years (1902-03 through 1913-14) which have been used for the United Kingdom, except that no prices could be given for 1905-06.

Feeders of hogs in Germany preferred barley, and at equal prices most did not use any corn at all. In 1912-13, corn was cheaper than barley by 8 per cent, and net imports of corn constituted 26.7 per cent of the total imports of corn and barley. Considering, however, that imported corn was used also for other purposes (production of starch, glucose, and alcohol) while a substantial amount of domestic barley was fed to hogs in addition to practically all the imports of that grain, the average percentage of corn in the grain ration of hogs may have been not much more than half as large as the ratio between net imports of corn to those of barley. In 1913-14, when corn was more expensive than feed barley by 9 per cent, net imports of corn fell from 1,154,000 to 836,000 metric tons. But the use of corn for purposes other than hog feed hardly declined much.³⁶ Hence the use of corn for hogs may have been contracted to slightly more than half

³⁶ Corn is worth materially more than barley for such purposes as starch and syrup. Moreover, factories built for converting these products cannot easily shift to other grains.

the amount of the previous year or probably to less than 10 per cent of the use of barley for this purpose. Monthly data would disclose that the use of corn as hog feed was almost negligible at corn prices materially above barley prices.

This comparison of the data for 1912-13 and 1913-14, however, shows not only a definite preference for barley as hog feed but also a great effect of the price relation between corn and barley on the use of corn for this purpose. The same conclusions are reached from the analysis of the data for the whole period covered in Chart 13.

The year-to-year variations in imports of corn into Germany cannot be explained by changes in corn prices, in several years. In 1903-04 imports of corn increased only by 3 per cent, although prices of corn fell by 11 per cent. In 1904-05 and 1911-12 both imports and prices of corn rose. The same occurred in 1905-06 (in comparison with 1903-04). In 1909-10 and 1913-14 both imports and prices of corn declined. Considerably more concordance can be observed with regard to the changes of the ratios of corn imports to the sum of barley and corn imports, and the changes of the ratios between corn prices and barley prices. In fact, the latter concordance was perfect, except that in 1910-11 the ratio of imports remained unchanged while the ratio between prices declined. Moreover, the ratios of imports of corn to those of barley in Germany in the prewar decade showed a decided declining trend. If this trend were eliminated, the ratio of imports in 1910-11 would have declined rather than remained unchanged, and the concordance between the changes in the ratios of imports and the changes in the ratio of prices would become perfect.

Close observation of the German feed-grain market during several postwar years leads the writer to believe that the large mutual dependence between the markets of corn and imported feed barley has been preserved.

There is hardly any doubt that the interdependence between the markets for imported corn and barley in Germany

in both prewar and postwar years was considerably greater than that between the total supplies and prices of corn and barley in major European countries. The principal reasons are probably two: the German supplies from imports go mainly into the same regions at approximately the same marketing costs; and producers of hogs from purchased feed, especially if many of them raise hogs as their major enterprise, are more eager to shift from one feed to another than those who produce hogs from farm-raised feeds especially if the latter raise only one or a few hogs mainly for their own needs.

The United States.—Lacking a reliable series of prices of feed barley for the eastern United States, we have to be satisfied with a comparison of the interconnection of oats and corn prices. Chart 14 shows supplies and prices of oats, ratios of the supplies of oats to the supplies of the three major feed grains, and ratios of oats to corn prices. In the prewar period, only two insignificant divergences can be found between the changes in the supplies and prices of oats. In 1905–06, oats prices remained unchanged, though supplies were larger by 6 per cent. The second case occurred in 1908–09 when a negligible increase (of 1.5 per cent) in the supplies of oats was accompanied by a negligible advance (of 2 per cent) in price.

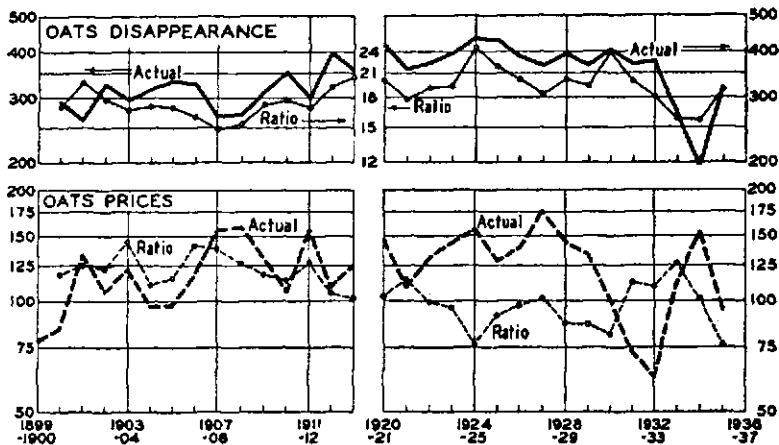
Moreover, the variations in the price ratios between oats and corn were strongly marked in the fifteen prewar years. The range of oats prices in terms of corn prices was from 102 in 1913–14 to 145 in 1903–04.³⁹ This again indicates a large independence of prewar oat prices from prewar corn prices. Killough,⁴⁰ in his correlation analysis of the factors “making the price of oats” in the period 1896 through 1915, even found that the “. . . . corn [crop] added as a variable does not increase the coefficient of correlation.” Change in the size of the available supplies of

³⁹ In 1901–02 oats were even more expensive than wheat, while in 1907–08 oats prices were within 1.5 per cent of the wheat prices (Chart 6, p. 87).

⁴⁰ H. B. Killough, *What Makes the Prices of Oats?* (U.S. Dept. Agr. Bull. 1351, 1925), p. 11.

CHART 14.—DISAPPEARANCE AND PRICES OF OATS, RATIOS OF OATS DISAPPEARANCE TO THAT OF CORN, OATS, AND BARLEY, AND RATIOS OF OATS PRICES TO CORN PRICES, IN THE UNITED STATES, BY YEARS, PREWAR AND POSTWAR*

(Million cents; cents per cental; logarithmic vertical scale)



* Disappearance represents production adjusted for net exports or imports (July-June data) and for changes in farm stocks and visible supplies—for corn, as of November 1 through 1927, thereafter as of October 1; for oats, as of August 1 through 1927, thereafter as of July 1.

oats was found to be the only significant factor, according to his computation;⁴¹ aside from this, oats prices were affected only by changes in the general level of farm prices.⁴²

Henry Schultz, it is true, has found that the (negative) coefficient of correlation between "consumption" per animal unit and farm prices of oats in 1896-1914 was improved by introducing as further variables the supplies of barley, corn, and hay.⁴³ But his coefficients of correlation between "consumption" and prices of oats in 1875-92 and 1899-1914 also were very high, pointing toward a high degree of independence of the oat market from those of the other feed

⁴¹ The coefficient of simple correlation between the Chicago price of oats and the United States production of oats was -0.82 . Killough, *op. cit.*

⁴² Killough writes in explanation of the failure to find any correlation between the prices of oats and the corn crop: "This may be partly owing to the fact that the corn crop tends to be small when the oats crop is small and large when the oats crop is large."

⁴³ Henry Schultz, *op. cit.*, pp. 552, 593.

grains. Such independence must probably be definitely accepted for the United States for prewar years, in spite of the fact that the possibility of substituting corn for oats and vice versa was much better known in this country than in the major importing countries of western Europe. Such superior knowledge was perhaps found primarily in the country rather than in the cities, and the demand for oats from the cities was a very important price-determining factor in prewar years.

Data in Chart 14 seem to indicate somewhat more dependence of oats prices upon the supplies of major feed grains in postwar years. In 1922-23 oats prices increased by 20 per cent, in the face of an increase of oats supplies by 5 per cent. The reason evidently was an even larger rise of corn prices. In 1924-25, supplies and prices of oats increased by 10 and 8 per cent, respectively. Again the underlying factor was apparently the strength of the corn market (corn prices advanced by 37 per cent). In the preceding year both supplies and prices of oats also changed in the same direction (but downward), again probably in sympathy with a similar but much larger change in corn prices.

R. W. Cox,⁴⁴ in his analysis of corn prices, found for the periods 1897-1915 and 1921-28 that "A 21 per cent increase in the production of these crops [oats and barley] has about the same effect on price [of corn] as a one per cent increase in the corn supply." The United States corn crop on the average is almost four times as large as those of oats and barley combined. Hence Cox's finding would mean that each cental of corn affects corn prices more than 5 times as strongly as a cental of the two other feed grains. This seems rather plausible for the whole period analyzed by the author (more than two-thirds of it was prewar). The data in Chart 14 indicate a lesser mutual effect of the corn and oats markets in prewar than in postwar years. Hence it is not improbable that in postwar years the effect of corn on oats prices, and

⁴⁴ R. W. Cox, *Factors Influencing Corn Prices* (Minnesota Agr. Exp. Sta. Tech. Bull. 81, September 1931), p. 19.

vice versa, was greater than computed by Cox. Nowadays a much larger proportion of oats is fed to animals other than horses than was the case before the World War, and the ease of substitution of oats for corn in these uses, and vice versa, is probably realized by feeders more generally than the possibility of substituting corn for oats as a horse feed. Moreover, in the meantime city horses have disappeared almost entirely, and the owners of city horses may have been the people particularly reluctant to substitute some other feed grain for oats.⁴⁵

Feed grains of different types and grades.—Differences in type and grade do not matter much in the feed-grain market, except for accompanying differences in the content of nutrients. Yellow corn is mostly preferred to white corn owing to its content of vitamin A. Moreover, in England poultry feeders seem to be prepared to pay a premium for yellow *flint* corn, particularly for small deep-colored flint corn,⁴⁶ but white corn is preferred there for finishing poultry.⁴⁷

Commercial poultry producers are probably reluctant to feed low grades of barley or oats to poultry, owing to the high fiber content of these grades; low-grade oats are unlikely to be used for expensive horses. Generally, however, there seems to be little inclination to evaluate higher grades of feed grains over lower grades sensibly higher than is justified by their larger content of nutrients, digestible nutrients, or net energy value.

⁴⁵ Henry Schultz's computations for corn (*op. cit.*, pp. 551, 593) yielded very high coefficients of correlation between the per capita consumption and the average farm prices in all three periods investigated by him (the third period covers the years 1915-29, excluding 1917-21), and the introduction of prices of oats, barley, and hay as additional variables made the fit somewhat worse. But the use of average farm prices for the whole United States in such computations seems open to question.

⁴⁶ *Maize* (Imperial Economic Committee, Report 28, London, 1934), p. 42.

⁴⁷ White corn in England also commands a premium over yellow corn for manufacture of edible starch, and to a lesser degree, for glucose. *Ibid.*, pp. 30-31. According to Paul Weatherwax, *The Story of the Maize Plant* (Chicago, 1923), p. 191, white corn also is almost universally used for starch products in the United States. But according to recent information from E. C. Boerner, Senior Marketing Specialist in the Bureau of Agricultural Economics, U.S. Department of Agriculture, mixed maize is almost exclusively used for this purpose, and the process employed by manufacturers does not justify premiums for corn of any color.

CHAPTER V

REGIONAL DIFFERENCES IN THE QUALITY OF GRAINS

Differences in the quality of the same grains as they affect usefulness were discussed at some length in the preceding chapter. Additional information on the subject, together with discussion of quality differences between the same grains as produced in different countries and regions and between different grains as produced in the same localities, is needed for analysis of the competitive power of different grains under various conditions.¹

Climate, soil, cultural practices, and breeding—the factors that determine the quantity of grain produced per acre—are also largely responsible for quality of grain.² Soil and especially climate are the most important factors. Breeding has to work within the limits set by natural conditions, and prices as well. It usually is not expected to sacrifice yield for quality. While breeding can boast great achievements in the quality of all grains, and especially of oats, indigenous wheats in most western European countries were of better quality than va-

¹ The literature on the quality of the grains produced in different parts of the world and on the main causes of these differences would easily fill a volume. For wheat the writer has relied primarily on William Jago and W. C. Jago, *The Technology of Bread-Making* (London, 1911); D. W. Kent-Jones, *Modern Cereal Chemistry* (Liverpool, 1924); E. A. Fisher and C. R. Jones, *The Wheats of Commerce. I. General Considerations* (National Joint Industrial Council for the Flour Milling Industry, Tech. Educ. Series Pamphlet 9, November 1932), and E. A. Fisher and C. R. Jones, *The Wheats of Commerce. II. Commercial Wheat Classes* (National Joint Industrial Council for the Flour Milling Industry, Tech. Educ. Series Pamphlet 10, August 1937); and on the works of Adam Maurizio and M. P. Neumann cited in chapter ii. Neumann's book and the publications of the Versuchsanstalt für Getreideverarbeitung und Futtermittelveredlung, Berlin, of which Neumann was one of the directors, contain ample data on rye. Much useful information on corn is found in *Maize* (already cited), and data on barley are given in H. C. Grant, *Barley Survey* (Empire Marketing Board, No. 62, London, March 1933).

² This would be a reason for treating this topic in the part of this study devoted to yields. The causes of large interregional variations in price ratios of different grains, however, cannot be fully disclosed without consideration of differences in quality of the grains produced, and since these price ratios are dealt with in this part of the study, it seemed advisable to discuss regional variations in quality at this point.

rieties developed by breeders which have replaced them; the same seems true of rye grown in most countries of the world. Still, future changes in quality by breeding, especially in countries where now bastard mixtures are grown, are likely to affect interregional and inter-grain competition.

THE SAME GRAINS IN DIFFERENT PLACES

The wheat that yields bread of large volume and fine texture is grown in drier climates and on soil naturally rich in nitrogen and especially in humus, i.e., on black or chestnut soils. Wheat grown in this environment usually possesses the requisite large amount of protein of good quality. Its skin is mostly thin, and the flour extraction is satisfactory in spite of the moderate plumpness of the kernels. The low water content and soundness common in such wheat add to its value. Poor soil, abundance of moisture, especially the combination of both, tend on the contrary to produce wheat with a small content of protein of poor quality. To make up the deficiency of the soil by fertilizers does not compensate for natural richness so far as grain quality is concerned. Moreover, wheat varieties of the poorest quality yield best under the conditions of intensive cultivation widespread in regions of moist climate. The skin of many wheats grown in moister climates is rather thick and the moisture content tends to be high, both factors mostly overcompensating the effect of the plumpness of the kernels on the yield of flour. This wheat, like any other grain grown in moister climates, also frequently shows some or a good deal of spoilage from having been harvested in unfavorable weather.

Some drier regions with soil containing little humus succeed in producing wheat of medium strength that is otherwise of excellent quality. This pertains especially to the color of the flour and its extraction. Materially more white flour can be produced of such wheat, especially if the wheat is white-skinned.

Canada produces the best bread wheat. The hard-spring-

wheat region of the United States, most Russian wheat regions, the hard-winter-wheat region of the United States, and Argentina follow approximately in the order mentioned. Hungary, once famous for its bread wheat, is still among the countries which can be proud of their produce. Wheat produced in all these countries and regions is of red color. The poorest red wheat exported in postwar years has originated in Rumania. Australia produces the best white wheat. Part of the white wheats from the Pacific Northwest states is of similar quality, but the remainder has only second rank. The poorest bread wheats are grown in northwestern and central Europe. That of Great Britain is probably the poorest, but the wheats grown in Germany, northern Italy, and countries with similar conditions are also poor.³

In postwar years Rumanian wheat has been rather regularly sold in British markets substantially below the price of English wheat. Indian is another cheap wheat, but both are exceptions. The quality of Rumanian wheats seems to have suffered severely from the subdivision of land shortly after the World War.⁴ Wheat of British India is often strongly damaged by weevils and possesses a strong odor.

In British markets most imported wheats usually command a more or less substantial premium over home-grown (Chart 15, p. 124).⁵ Argentine Rosafé, a wheat of medium strength, sold at 9 per cent more than British domestic wheat on the average in 1932-33 to 1936-37, whereas No. 3 Manitoba, an average grade of the strongest wheat, had approximately as large a premium over Rosafé. The relative decline in the

³The poor quality is primarily the result of abundant precipitation. But the worst wheats are those developed by breeding conducted exclusively with a view to larger yields. All attempts to attain high yields without sacrificing quality have thus far failed. The available varieties of fair baking quality, such as Yeoman in Great Britain and Janetsky's Early Spring and Lang's Tassilo in Germany, are produced in relatively small quantities only. In Germany such wheat amounts to 5 per cent of the total.

⁴See V. P. Timoshenko, "The Danube Basin as a Producer and Exporter of Wheat," *Wheat Studies*, March 1930, VI, 235.

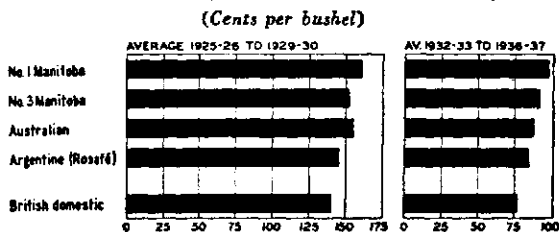
⁵See chart in A. F. Wyman and J. S. Davis, "Britain's New Wheat Policy in Perspective," *Wheat Studies*, July 1933, IX, 339.

evaluation of white wheats in recent years was mentioned on page 96. In the five crop years ending with 1929-30, Australian wheat averaged 2 per cent higher in price than No. 3 Manitoba; in the five years ending with 1936-37 it was 4 per cent cheaper.

The effect of the difference in quality of wheat is so strong that it not infrequently overshadows the effect of marketing costs. For example, Denmark, a deficit country, stands in fifth place in the array of wheat prices in Chart 18 (p. 137), while Melbourne occupies the seventh or eighth place. California, a distant deficit region in wheat, is also found among the typical surplus markets, with the price of its undesirable wheat.

The factors determining the quality of durum wheat are similar to those for common wheat, except that practically no durum wheat is produced in regions of heavy precipitation. Vitreous, nearly translucent durum, so much desired for the production of macaroni and similar pastes, is grown solely on chernozem and chestnut soils. Durum from soils containing little humus and nitrogen, on the other hand, is low in protein and contains a very high proportion of starchy and semistarchy kernels, which impart a specky appearance to the pastes manufactured from them and also reduce their plasticity. Russia, Manitoba, and the Dakotas and Montana produce the good durums, while durums grown in the Medi-

CHART 15.—AVERAGE PRICES OF SELECTED IMPORT WHEATS AND OF DOMESTIC WHEAT IN GREAT BRITAIN, IN TWO FIVE-YEAR PERIODS, POSTWAR*



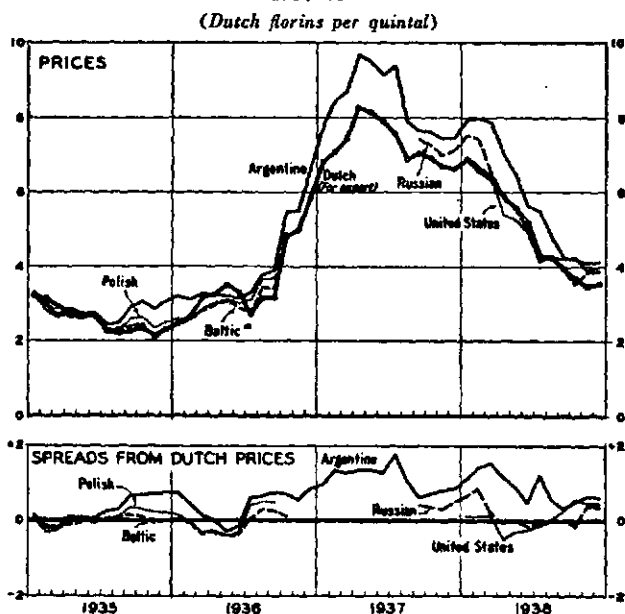
* Prices of import wheats are c.i.f. United Kingdom, including import duties, if any; and those of British domestic wheat, the *Gazette* average—both chiefly as given in *Wheat Studies*, December 1937, XIV, 181.

terranean countries are much less satisfactory. Substantial premiums are paid for desirable qualities.

The position with regard to the quality of rye is similar to that of common wheat, except that the tendency of moist climate to enlarge the thickness of the skin seems to be more pronounced. Another difference is that sandy soil apparently does not impair the quality of rye. Argentina, and the drier portions of Russia, Canada, and the United States, approximately in the order mentioned, are the producers of good rye, while northwestern and north central Europe grow the poorest kinds.

The price differentials for rye of different quality in recent years (Chart 16) are unfortunately not very typical. Un-

CHART 16.—PRICES OF RYE OF DIFFERENT ORIGIN AT ROTTERDAM, MONTHLY, 1935-38*



* Data are averages of Thursday quotations (in occasional instances, of only two or three in a month), obtained through the courtesy of the Foreign Agricultural Service Division, Bureau of Agricultural Economics, U.S. Department of Agriculture.

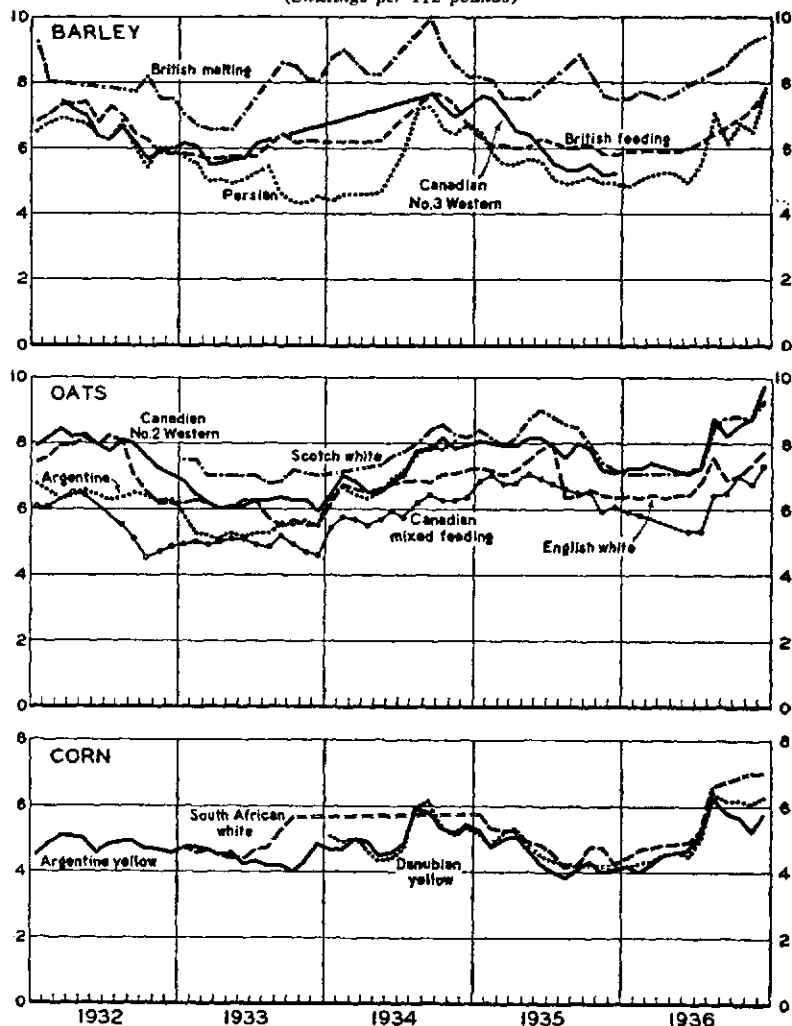
* Consists of small quantities of Lithuanian, Latvian, and/or Estonian rye. When the quotations were not identical, a simple average was used.

usually small supplies of rye of good quality were available for export in the years covered by the chart. Argentine rye was practically the only good rye offered. Moreover, Argentina is a very erratic exporter; since her rye is largely a by-product of the livestock industry (p. 490), exports vary greatly from year to year with little regard to price. On the other hand, exports of the poor ryes—Polish and particularly Dutch—are subsidized. Argentine rye nevertheless averaged in price only 8 per cent higher than Polish rye and only 11 per cent more than Dutch rye in 1935. In 1936 Argentine rye was more expensive than Polish and Dutch rye by 10 and 11 per cent, respectively. In 1937 and 1938 these price differences were a little larger. However, a slightly more liberal supply of imported rye of good quality did not fail to bring its price down to the level of the poor Dutch or Polish products (compare the prices in January–May 1935 and April–June 1936).

Argentina and the Danubian countries grow yellow flint corn, which is preferred by most feeders in the importing countries, while the United States produces practically only dent corn. South Africa has a good but limited market in Europe for its white dent corn for the manufacture of starch. Yet substantial differences rarely arise in return to corn producers owing to variations in the type of corn produced, except locally. Prices in Chart 17 show a surprising concordance of prices of corn of different types in world markets; only white corn may be an exception when it is offered very sparingly. Differences in the quality within the same types may be more important under specific conditions. Corn grown near the northern margin of its penetration does not reach maturity before the first killing frost every year. In these regions, the percentage of damaged corn is usually high, and the moisture content of the remainder is considerably above that in regions where corn has more time for conditioning. This is clear from the percentages of merchantable corn ascertained by the U.S. Department of Agriculture. Only 56 and 60 per cent of corn was merchantable in North Dakota and Montana

CHART 17.—PRICES OF BARLEY, OATS, AND CORN OF DIFFERENT ORIGIN AND GRADE AT BRITISH PORTS, MONTHLY, 1932-36*

(Shillings per 112 pounds)



* Data from *Agricultural Statistics* (Great Britain, Ministry of Agriculture and Fisheries), Vol. II.

on the average of 1920-29 as against 79.6 per cent on the average for the United States.⁶

⁶ See *Crops and Markets*, November 1931, VIII, 459. ☉

In respect to the effect of climate and soil on protein content and some other properties, oats and barley do not display any difference from the other grains. But the proportion of the almost worthless hull of these grains shows a strong tendency to become larger in dry climates and particularly in dry heat. The thickness of the hull is also a variety characteristic.⁷ But the effect of climate is the stronger one. The prolonged ripening of grain, undisturbed by shortage of moisture, enables a complete filling of the kernels, whereas premature ripening, entailing insufficient filling, is characteristic of grain grown in drier climates.

The differences in the proportions of the hull of barley and oats as produced under different climatic conditions are fairly well reflected in the average test weight of these grains in different states.⁸ Variations in the average test weight of winter wheat from state to state are within 5-6 per cent, the highest average being 60.3 and the lowest 56.9 pounds per measured bushel. The variations in the test weight of spring wheat are slightly larger but do not exceed 7-8 per cent (ranging from 59.8 to 55.7 pounds). Moreover, the inverse correlation between precipitation and test weight is only slight. Winter wheat produced in Kansas, Oklahoma, and Texas, for example, show satisfactory average test weights. The ranges of average test weights of barley and oats, however, are substantially wider than those of wheat. That for barley is equiv-

⁷ Variations in the proportion of the hull are large even between barleys and oats produced side by side on the same field. According to H. H. Love and others, *Improved Oat Varieties for New York and Adjacent States* (U.S. Dept. Agr. Circ. 353, August 1925), p. 12, the content of caryopsis ("meat") in the eight varieties of oats tested in 1921-23 in the experiments at Ithaca, N.Y., varied from 64 to 75 per cent. The caryopsis of some untested varieties was equivalent to 60 per cent of the total weight. The variations in flour extraction from different varieties of wheat or rye produced in the same (or different) places never reach such proportions. For example, the 13 varieties of Argentine wheat tested in the grain laboratory of the U.S. Department of Agriculture showed a range in yield of flour (basis dockage-free wheat) from 66.3 to 72.8 per cent only, according to D. A. Coleman and others, *Milling and Baking Qualities of World Wheats* (U.S. Dept. Agr. Tech. Bull. 197, October 1930), p. 82.

⁸ *Crops and Markets*, November 1931, VIII, 459. The expression "fairly well" is used advisedly, because it is rather difficult to account for some differences. Barley and oats are mostly fed on farms; hence farmers may be less anxious to produce grain of high test weight. For the same reason, farmers who report on the test weight to the Bureau of Agricultural Economics may not be very accurate in their statements with regard to the test weight of feed grains.

alent to 13–14 per cent (43.6 pounds the lowest and 49.4 the highest) and that for oats amounts to almost 25 per cent (29.9 pounds the lowest and 37.4 the highest). Such test weights as 43.6 pounds per Winchester bushel of Kansas barley indicate a product which has a moderate value even as feed.*

Conditions in the United States, except locally, are not very favorable for production of high-quality barleys and oats. The data of Nat C. Murray, a crop statistician of long experience, indicate for the average of 1935–38 an average test weight of oats in the United States of only 30.1 pounds per measured bushel. Barley and oats produced in Canada, where it is much cooler, are in general materially superior in quality to the United States produce; this may be particularly true of oats, which like cool weather more than any other grain. The Canadian superiority is clearly reflected in the official grade requirements. The minimum test weights prescribed are as follows in pounds per Winchester bushel:

Grade	Barley			Oats			
	United States	Canada		United States		Canada	
	Classes I and II	Six-row and Trebl	Feed	White, red, gray, black, or mixed oats	Feed and mixed grains	Oats	Feed
1.....	47	48.4	....	32	32	36.8	32.9*
2.....	46	47.5	....	30	29	34.9	27.1
3 extra....	..	46.5	....	..	..	....	....
3.....	43	....	45.5	27	26	32.9	....
4.....	40	....	44.6	24	..	....	....
5.....	35	....	40.7	..	..	....	....
6.....	..	....	....	..	..	....	....

* No. 1 extra feed, 36.8 pounds.

* The much larger variations in the test weight of hulled and hull-less grains are also clearly reflected in the minimum requirements of the official standards. In the United States, for example, the minimum test weight of the lowest grade of most classes of wheat is 15 per cent lower than that of grade 1; for rye the difference is only 12.5 per cent, but for barley and oats it amounts to 24.4 and 25 per cent, respectively. The difference for corn is larger than that for wheat or rye only because the permitted moisture content increases from higher to lower grades, whereas the maximum moisture content is the same for all grades of the other grains mentioned. Similar differences in the margins between the required minimum test weights of the highest and lowest grades of different grains may be found in the grading regulations for other countries. See also N. Jasny, *Die Standardisierung von Getreide* (Schriftenreihe des Instituts für landwirtschaftliche Marktforschung, Heft 4, Berlin, 1932).

Moreover, in Canada the quality of the different grades usually is above their minimum requirements much more than is true of the United States, though the proportion of the crop falling into lower grades is considerably larger in Canada.

Northwestern and central Europe produce barley and oats of even higher quality. Some years ago the introduction of a grading system was contemplated in Germany. The proposed test weights for feed barley and oats, which did not meet with objection, were as follows in pounds per Winchester bushel:

Grade	Feed barley		Oats
	Winter	Spring	
1	52.1	52.1	42.5-43.3
2	49.7	50.5	40.5
3	47.3	48.1	37.7

The minimum test weights of the lowest grades of feed barley proposed for Germany were higher than the minimum test weight of the highest grade in the United States. The difference in oats was even larger.

English barleys usually average around 54 pounds per Imperial bushel (about 52.3 pounds per Winchester bushel), according to Grant.¹⁰ English oats probably also are heavier than German oats. Yet the English mills producing rolled oats are not quite satisfied with their own oats but definitely prefer Scotch oats, famous for plumpness and thin skin. Swedish oats also are renowned for their quality throughout the world.

High moisture content and damage from unfavorable harvest weather, which are characteristic of wheat and rye in northwestern and north central Europe, also distinguish barley and oats of the same origin. But the much lower content of hulls in the latter frequently more than offsets these defects. This is true even for use as feed. Still more valuable are the thin-skinned barleys and oats in most other uses. High premiums are paid for such qualities, particularly in regions which produce only grains with thick hulls.

¹⁰ H. C. Grant, *op. cit.*, p. 53.

Barley produced in dry climates is only exceptionally used in the preparation of beer, and that grown on prairie land in dry climates is even less suitable for this use. Slovakia is commonly considered to produce the best malting barley in the world;¹¹ but portions of Germany, Denmark, and even of Great Britain also produce good malting barleys. Of the export barleys, California produces its sunshine barley. The surpluses of the eastern United States, if any, consist of less than fair feed barley. Canada exports feed barley of varying quality. The higher grades of Canadian barley represent an excellent feed and are also used freely in the manufacture of groats and by distillers of barley. Russia, the Danubian countries, Argentina, North Africa, and British India are exporters of feed barleys of fair to low quality. Chile and Australia occasionally have small surpluses of malting barley of fine quality.

A glance at Chart 17 (p. 127) suffices to indicate how wide are the price differentials between different barleys as compared with those of corn, a naked grain. This conclusion holds even if the prices of British (and other similar) malting barleys are disregarded. British feed barley, a product from which everything of better quality is picked out, sold at 9 per cent over Persian in January–June 1932; in September 1934 to June 1935 the corresponding price differential averaged 6 per cent, and in the same months of 1935–36 it was 17 per cent. In 1932 Russian, a feed barley, was 25 per cent more expensive than Argentine, another feed.¹²

The array in Chart 18 (p. 137) shows furthermore that differences in quality of barley, especially of malting barley, are able to offset largely the effect of marketing costs on the position of markets arranged according to prices. In 1909–13 the price of malting barley in Melbourne was highest of all included in the array. Prague, an export market, had a

¹¹ J. A. S. Watson and J. A. More consider English malting barley the best. See their *Agriculture; The Science and Practice of British Farming* (already cited), p. 178.

¹² There was not enough room for the prices of Russian and Argentine barleys on the chart.

higher price than Great Britain, a deficit country, in postwar years.

Of the exported oats, the sparingly offered Chilean oats (moist climate) usually take first place. The better grades of Canadian oats follow, while Argentina exports a rather poor product. Russian oats are between the two in quality. The scatter of the prices of oats in Chart 17 is even wider than that of barley prices and differs surprisingly from that shown by corn prices. Scotch white leads the other oats, with prices occasionally as much as 75 per cent above the prices of the cheapest oats. The price differential remains large even if Scotch oats are left out of consideration. The price difference between No. 2 Canadian and Canadian Mixed Feed oats is occasionally as large as 35 per cent.

DIFFERENT GRAINS IN THE SAME PLACES

Thus the grains as produced at the same places are not necessarily all of good or all of poor quality. Northwestern and north central Europe in general produce very poor wheat, mediocre rye, but excellent oats and good-to-excellent barley. Owing to these quality differences, the price ratios in these countries are materially more favorable to domestic than to imported oats and barley. In the prewar and postwar prosperity periods, the prices of imported oats averaged in import markets 27 and 29 per cent lower than similar prices of wheat (see "world market" prices in Chart 3, p. 11). But the difference in prices between domestic oats and wheat was only 12 and 16 per cent, respectively, in Great Britain in the same periods. In the Netherlands, corresponding figures were 16 and 20 per cent, and in Denmark only 10 and 16 per cent.¹³

Chart 3 (p. 11) shows further that in 1925-29 the prices of imported rye exceeded similar prices of oats by 18 per cent. In the Netherlands and Denmark, however, domestic rye was higher in price than domestic oats by only 3 and 5 per cent,

¹³ Price ratios between domestic grains in recent years cannot be used for these comparisons, owing to the distorting influence of import duties and other means of protection.

respectively. The materially better prices of domestic oats relative to those of wheat and rye must perforce greatly strengthen the competitive position of oats in these countries.

The "world market" prices of barley in Chart 3 are not strictly comparable with the prices of domestic barley in most importing countries, for they are prices of feed barley, while the prices in the importing countries are mostly averages of all domestic barley. Yet the comparison of prices of imported feed barley and domestic barley enables one to form an idea of the situation in which barley production in the importing countries would be if they were able to produce only feed barley, as are so many important export regions. Both in the prewar and postwar predepression periods the average prices of all domestic barley in Great Britain and Denmark were practically equal to those of domestic wheat. In Belgium and the Netherlands they were lower than the domestic wheat prices by only about 5-10 per cent. The differences would have been about 25 per cent if the climate of these countries permitted the production of only feed barley of average quality.

While the quality factor brings the prices of domestic wheat and barley in northern Europe close together, the same factor places barley above rye. In the five years ending 1936, barley was more expensive than rye by 11 per cent in Belgium and by 18 per cent in Denmark. As we move south within Europe, the quality of oats and barley declines, and with this the relative price advantage in favor of these grains dwindles. The ratios of prices of oats and barley to wheat in Spain and Italy have been largely affected by the difference in the amounts of protection, but the poorer quality of the hulled grains in southern Europe is undoubtedly also a factor reducing their competitive strength as compared with that in countries farther north.

Marked effects of the quality factor with respect to the different grains as produced in the same country or region can also be found outside of western Europe. Chile produces

excellent oats and barley but a white wheat of only moderate quality. One of the reasons for the relatively favorable price ratios of barley and oats to wheat in the Pacific Northwest of the United States is the fact that the wheat produced in those states can find an outlet only at rather low prices. In California the position of wheat is weakened further, since this is even poorer than that farther north while part of California barley finds a market for malting purposes. In contrast, the regions of this country producing the most desirable bread wheats—the hard-spring-wheat and hard-winter-wheat regions, the former producing also good durum and fairly good rye—grow medium to very poor oats and barleys. While in California, in spite of the immense amounts of barley produced, barley prices average about 75 per cent of wheat prices (Chart 4, p. 12), in North Dakota the farmer can expect to get for his barley only about 60 per cent of the price of wheat (Chart 2, p. 10). This difference seems large enough to account substantially for the fact that barley is the leading grain crop in California with wheat considerably behind, while in North Dakota barley is but a very poor second to wheat.

Argentina produces excellent rye, fair wheat, but rather mediocre barley and oats. As shown in Chart 2, Buenos Aires prices of barley and oats are usually only slightly higher than those of corn. In 1909–13 oats were even cheaper than corn, and Argentine corn, though a grain of good quality, sells for only a low price in import markets.¹⁴

Russia grows good wheat and rye, but experiences difficulties in finding suitable regions for producing the small amounts of malting barley needed for home use. While the good wheat as well as barley of average quality exported from Russia originate in drier regions, the oats of fairly good quality come from areas well supplied with moisture. Oats of Russia's drier regions are poorer than the exported product.

¹⁴ The fact that in Argentina oats are cheaper than corn reflects the higher marketing costs on oats. The Argentine rye price average of 1932–36 strikes one as somewhat low, and the writer has no explanation for it.

Only the Prairie Provinces of Canada are fortunate enough to have for sale the best wheat in the world, good rye and oats, and barley suitable for all purposes other than malting.¹⁸ Favorable soil and climatic conditions, advanced technique of breeding and grading grain, and last but not least a great responsiveness of farmers: these combine to explain this somewhat unusual occurrence. Chart 2 shows that in postwar years, oats in Winnipeg were cheaper than wheat by only 13 to 20 per cent. The narrowness of the margin is caused partly by the fact that No. 2 Canadian Western oats are an over-average grade, while No. 3 Manitoba Northern wheat is slightly under-average; another reason is that wheat but not oats was always on an export basis; but the generally good quality of Canadian oats might also have been a factor.

¹⁸ In Canada domestic barley is used also for beer production.

CHAPTER VI

MARKETING COSTS

We have thus far discussed that part of the large variations in price spreads between the several grains at the same places (Charts 2 to 4, p. 10-12) which can be traced to preferences of consumers for specific grains and to differences in quality of different grains as produced in the same localities. Protectionist measures and differences in the cost of production are further factors; they will be discussed later. But a substantial portion of the divergences in inter-grain price ratios, often the larger portion, is due to the effect of the cost of marketing grain from surplus to deficit regions.

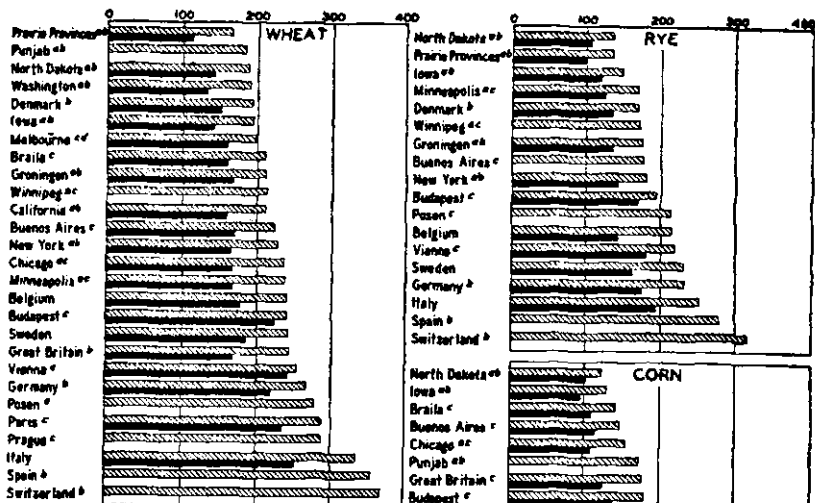
Marketing costs, moreover, are the factors which act most universally and persistently, strikingly in contrast with protectionist measures. Except in such small countries as Belgium, marketing costs materially affect production, consumption, and trade in grains not only between but within countries, while protection in general affects only the situation of whole countries. A short time ago several important grain-deficit countries admitted grains free of duty; and these, together with the surplus countries, formed a vast territory with marketing costs mostly the outstanding factor determining inter-market spreads and inter-grain ratios.

The inter-grain price ratios at the same places are *indirectly* affected by marketing costs. The spreads *directly* affected are the interregional price spreads of the same grains at different places. The arrays of grain prices in different countries and regions in Chart 18¹ show that, by and large, the positions occupied by different countries and markets in the arrays coincide rather closely with their positions with

¹ Unfortunately the prices in the arrays are not entirely comparable. Some of the farm prices are at railway stations, others are prices on the farm, and in the case of prices in Victoria a deduction is made from the prices received by producers for the outlay for commercial fertilizer and for some other costs. Similar and other differences, however, hardly vitiate the broad conclusions we draw from these arrays.

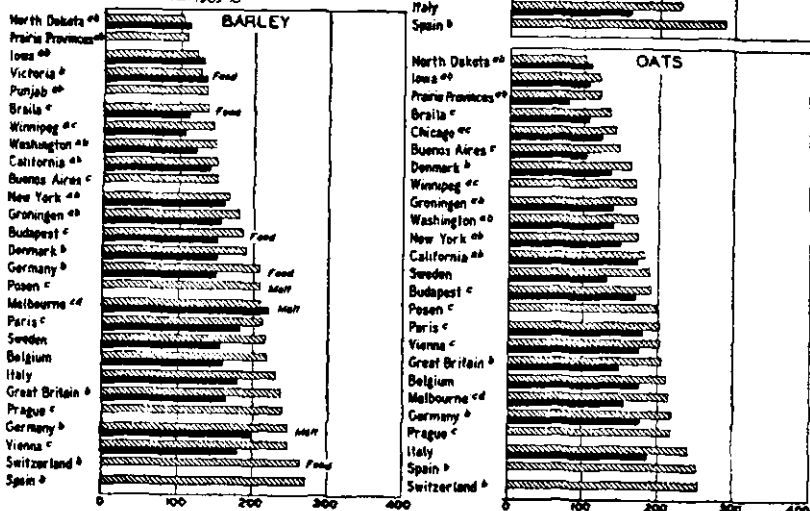
CHART 18.—ARRAYS OF PRICES OF GRAINS IN SPECIFIED PLACES, AVERAGES FOR 1925-29 AND 1909-13

(Cents per cwt)



NOTES

For details on sources and qualities see notes to Charts 2 to 4.
^aCrop years beginning August. ^bFarm price. ^cMarket price.
^dFebruary-March prices (postwar, 1927-30).
 1925-29
 1909-13



regard to marketing costs. Surplus countries tend to be at the top of the arrays, while deficit regions are mostly found at the bottom. Farm prices in North Dakota and the Prairie Provinces, for example, are almost persistently the lowest among the data presented. It will surprise many to learn that the average farm price of corn in the states of California and Washington is materially above that paid by feeders in several European importing countries. Data in Chart 18 also reveal the large magnitude of interregional price spreads between different grains. Marketing costs of course are not the only factor involved, but, except in recent years, they are in the main the most important one.

Since the inter-grain price ratios at the same places, so far as they are due to marketing costs, merely reflect the effect of marketing costs on interregional price spreads of different grains, it becomes necessary to include interregional price spreads in our observations. Moreover, interregional price spreads affect the competition among grains in the world not solely through their effect on inter-grain price ratios. The role of grain production in a given area depends greatly on the absolute level of grain prices in that area, and since the competitive positions of the grains are not the same in different areas, their competition in the world is indirectly affected by the price increases brought about by marketing costs and tariffs.

The two important features of marketing costs which are largely responsible for these effects are (1) that interregional spreads in prices of grains (comparatively cheap products) which are due to the addition of marketing costs are usually more or less substantial; and (2) that costs of marketing grain from any surplus region to a deficit region are about equal for both the more expensive and the cheaper grains.

Because marketing costs between surplus and deficit regions tend to be rather high relative to grain prices, production of grain is stimulated, and consumption hampered, in

deficit or borderline regions. Because marketing costs are about equal for different grains, while their prices vary, the inter-grain ratios in terms of percentages tend to become less as marketing costs rise; and inter-grain ratios rather than inter-grain spreads in terms of dollars and cents tend to be the decisive factor in the competition of grains for the consumer and the land. In deficit or borderline countries, therefore, marketing costs stimulate the production and hamper the consumption of the *cheaper grains* more than they affect the more expensive grains.

The fact that marketing costs show the tendency to be rather high relatively also causes interregional trade in grain to be restricted. The major fraction of world grain production is indeed consumed on the spot, in producing regions and even on the farms where it is grown. It is the international trade in cheap grains again which is the more affected.

Aside from the high and about equal marketing costs, two other circumstances reinforce these tendencies with respect to feed use of grain: (*a*) marketing costs of most other feeds conveniently fed along with grains are even higher relative to their farm value than is true of grain, and the use of these feeds on the farms where they are grown is even more advantageous than such use of feed grain; and (*b*) converting feed into animal products on the farms producing the feed does not meet with serious technical obstacles, such as are encountered in converting grain into flour or beer on the farms.

The fact that grain is mainly consumed on the spot means that the kind of grain available on the spot is the kind primarily consumed. With regard to feeds, the commonest adaptation is to adjust the types of livestock kept to local conditions of crop production. So far as these adjustments are imperfect, the advantages gained from using the grain on the spot involve consumption of kinds of grain less suitable for particular purposes, and production of kinds of grain less suitable for particular conditions.

NATURE OF OPERATIONS INVOLVED

A discussion of the character of operations involved in the marketing of grains as it affects the marketing costs of different grains seems appropriate at the outset. Such a discussion discloses the reasons for existing similarities and differences between the marketing costs of different grains, and for possible changes in the relative size of these costs in the future. Yet the subject is so technical that it seemed appropriate to include in the main body of the study only a short statement, supplemented by a more detailed discussion found in Appendix Note A.

Before discussing different operations, let us remark that all through this section two different types of cost have to be carefully distinguished: the cost to those who perform the operation, for example, transport or store the grain, and the cost to the shipper of the grain. These costs may sometimes be the same, but more frequently they are not. The owners of railways, elevators, and the like do not often charge the shippers precisely the handling cost which each of the grains involves.

Marketing costs to the shipper include the costs of transportation, elevator charges, expenses and profits of intermediaries, and all other costs involved in transferring the grain from producer to consumer.² All these costs can be subdivided into four groups according to the factor on which the charge is based: (1) value of the grain; (2) its bulk; (3) its weight; and (4) its bulk and weight.

Only such minor items as interest, shrinkage, and insurance represent a certain fraction of the value of the grain and are independent of either bulk or weight of the grain. Of these two, bulk is the more important factor for those who perform the operation, while weight is the more important to the shipper of the grain.

² For present purposes, we may regard as the consumer the miller, brewer, feeder, or other user of the grain, rather than the ultimate consumer of the grain products.

Grains vary greatly in bulkiness.³ The differences largely depend on whether the grains emerge from the thresher encased in the hull or free from it. Of the naked grains, wheat somewhat exceeds corn and rye in test weight, but the difference is small. Between rye and wheat, at least, the actual difference is usually even less than the 6.67 per cent implied in the legal weights of bushels of these grains. The test weight of barley, on the other hand, is frequently around 80 per cent and seldom is more than 85 per cent of that of wheat. The test weight of the best oats is about 70 per cent of that of wheat, while a measured bushel of oats grown in Nebraska weighs only about half as much as a measured bushel of wheat.

It makes little difference to the railway whether a car is loaded with 1,000 centals of wheat or 600 centals of oats. Since less light grain can be loaded in a car, all such supplementary costs as inspection or weighing also become dependent on the test weight. Furthermore, the factor of volume is, and especially was in the past, an important factor in water transport. It is a minor factor, and frequently of no significance whatever, only in transport on the road. The cost of construction and upkeep of storage space is inversely proportionate to the test weight of the grain. So far as the handling of grain in warehouses is mechanized, its cost also is inversely proportionate to or mainly dependent upon the test weight. Low test weight is such an obstacle to cheap marketing that the test weight of oats, the lightest grain, is sometimes increased by "clipping" off the ends of the kernels, though this involves a small cost and impairs the keeping quality of the grain.

So far as concerns the owner of the grain who pays the

³Bulkiness of grain is referred to as its test weight; in the United States it is measured in pounds per measured (Winchester) bushel. A distinction must be made between the test weight per measured bushel and the legal weights of bushels of different grains. While the first is different for each lot, the second remains unchanged. In the United States, for example, the legal weight per bushel is 60 pounds for wheat, 56 pounds for corn and rye, and 48 and 32 pounds for barley and oats, respectively. These legal bushels are not volume but weight units. The resemblance between the test weights per measured bushel and the legal bushel weights results from the fact that the latter were fixed not far from the average test weights of each grain.

charges rather than bears the actual costs, the weight of the grain is in general much more important in determining the amount of marketing costs than is its test weight. Indeed, lighter grains are sometimes charged less per unit of weight than heavier grains, although the cost of the operations to those who perform them are higher, simply because the heavier grain is more expensive and can bear the higher charges. But this adjustment of the charges to the ability of the grains to bear them is limited. At most, charges on lighter grains are only slightly below those of wheat on a basis of weight. Nothing approaching proportionality between total marketing costs and prices of the individual grains is ever reached. Moreover, when total marketing costs of the lighter grains are less than those of wheat, the grains thus favored tend to be corn or rye, which are materially cheaper than wheat but have a test weight only slightly lower.

To a surprisingly large extent, the differences in charges for transportation, handling, storage, and the like, on heavy and light grains are dependent upon the customary or legal trade unit. The charges on light grains are much less burdensome in countries where the unit of weight is the same for all grains (as where the metric system holds sway) than they are in countries where lower weight units are used for lighter grains.⁴ Canada is the country where and from which coarse grains are most discriminated against as to marketing costs. The situation probably is similar in Australia, and not quite so unfavorable for coarse grains in the United States.

MARKETING COSTS COMPUTED

It is unnecessary here to consider more than some typical marketing costs, and only those involved in international trade will be discussed in any detail.

⁴ See details in Appendix Note A. Sometimes, however, producers of light grains also have an advantage from the unequal weight units. The import duty on rye in this country is 15 cents per bushel and that on oats 16 cents. It was hardly the real purpose of the lawmaker to give oats 87 per cent more protection than was bestowed upon rye, though the consumers of rye can bear a higher price more easily than the users of oats. If the duties were levied per 100 pounds, they probably would differ less than they actually do.

On wheat.—According to the computations of the Board of Grain Commissioners of Canada (Table 4), transportation and handling charges on wheat from the Canadian Prairie Provinces to c.i.f. British harbors⁵ in 1938 averaged 34 cents

TABLE 4.—APPROXIMATE AVERAGE TRANSPORTATION AND HANDLING CHARGES ON WHEAT BETWEEN THE CANADIAN PRODUCER AND ARRIVAL AT BRITISH PORTS, 1938*

No.	Item	Cents per bushel
1.	Handling at country elevator ^a	4.00
2.	Railway freight from average western point to Fort William— Port Arthur	12.55
3.	Handling at terminal ^b	1.50
4.	Lake freight from terminal to Montreal-Sorel—Three Rivers— Quebec ^c	6.30
5.	Freight and insurance (marine and outturn) between Cana- dian ^d and British ports	9.65
	Total between producer and c.i.f. British port.....	34.00

* As yet unpublished data kindly furnished by E. A. Ursell, Statistician, Board of Grain Commissioners. Corresponding estimates for several earlier calendar years can be found in Dominion Bureau of Statistics, [annual] *Report on the Grain Trade of Canada* . . . For 1936 the comparable total was 30 cents. Corresponding estimates for shipment via Vancouver—New Westminster totaled 34 cents in 1938 and 31.5 cents in 1936.

^a Including insurance against loss by fire and storage for 15 days, official inward inspection, weighing and registration fees, and selling to exporter in Winnipeg.

^b Including insurance against loss by fire or explosion, storage for 15 days, official outward inspection and registration fees, and loading on vessel.

^c Including the cost of trimming cargo, brokerage, lake and outturn insurance, and any charges incurred for transfer of cargoes from upper lake to canal-size vessels.

^d Including fobbing charges there.

per bushel (56.7 cents per cental) via both Montreal and Vancouver.⁶ The computation does not include such items as remuneration of intermediaries (except that provided under item 1 in Table 4) and interest. The costs involved in these items may amount to 2–3 cents per bushel, if the wheat moves practically without interruption. Furthermore, the costs computed may be termed minimum costs. The charges under

⁶ The "c.i.f." cost does not include any outlay in the port of destination.

⁷ For some earlier years, detailed data on marketing costs between Fort William—Port Arthur and Liverpool may be found in Katherine Snodgrass, "Price Spreads and Shipment Costs in the Wheat Export Trade of Canada," *Wheat Studies*, March 1926, II, 177–202.

item 1, for example, apparently apply only to grain sold by farmers in carloads and are frequently higher even in this case. Country elevator handling of wheat sold in less than carloads ("street grain") involves an additional cost of some 2 cents per bushel. The Bureau recorded the cost for wheat moving through Atlantic ports by the all-water route from the head of the Lakes to Montreal—the cheapest way. But much Canadian wheat is transferred from the water to the railway in Buffalo or at Canadian lake ports in the east, in which event an additional cost of about 2 cents per bushel is involved.

Altogether, a fairer estimate of average marketing costs per bushel of wheat from the Canadian Prairie Provinces to the British harbors in 1938 seems to be 40 cents per bushel. This figure should approximately check with the spread between the prices of Canadian wheat in Canada and the United Kingdom.⁷

Only part of the wheat has reached its destination when it has arrived at a British or some other harbor in an importing country. Some wheat is reshipped to the interior. The additional costs from the harbor may be substantial if the ultimate destination is Switzerland, Austria, or the like, or even economically distant points in such large countries as France or Germany. If the wheat is shipped direct to the Mediterranean or Scandinavia, the ocean freight also is higher than reckoned in Table 4. The average cost of marketing Canadian wheat from the producer to the European miller was in 1938 somewhere between 40 and 45 cents per bushel. It may have exceeded 45 cents, if the cost of hauling from the farm to the shipping point is added.

⁷ Such check has been made for the marketing costs in 1936 and a few preceding years; these were estimated for those years at 35 cents per bushel. The farm price of wheat in the Prairie Provinces on the average of the crop years 1932-36 was 55 cents. The price of No. 3 Manitoba c.i.f. United Kingdom in the same years was 91 cents. The difference of 36 cents needs to be increased by one cent, the amount by which the weighted average price of all grades of Canadian wheat exceeded the price of No. 3 Manitoba in those years. (Compare the weighted average price of Canadian wheat with the price of No. 3 Manitoba in Winnipeg in J. S. Davis, "The World Wheat Situation, 1936-37," *Wheat Studies*, December 1937, XIV, 180.)

The costs of marketing wheat from the Canadian Prairie Provinces to European importing countries are somewhat above the weighted average for exported wheat generally. Wheat marketing costs from most points of surplus production in the United States are slightly higher than from the Prairie Provinces, but from Australia they are lower and from Argentina materially lower. Using the data for the years 1925 to 1927, the writer computed total marketing costs of wheat to European import markets at 46.5 to 48 cents per bushel for the Prairie Provinces, 46 to 47 cents for the Pacific Northwest states, 48 to 49.5 cents for the hard-winter-wheat region, 50.5 to 55 cents for the hard-spring-wheat region, 47.5 cents for Australia, and 37 to 38 cents for Argentina. The costs as computed included the outlay on sacks for the Pacific Northwest, Argentina, and most of the Australian wheat.⁸ Since that computation was made, the situation has become relatively more favorable for countries and regions with a long water haul. Argentina and Australia were particularly favored by extremely low ocean freight rates during the last depression.⁹

While in the export trade at least part of the route is regularly by water, a very large portion of domestic trade is served exclusively by land transport. This is one of the reasons why marketing costs borne by export grain exceed the costs involved in serving the domestic markets by much less than would correspond to the difference in distances. Another reason is that higher railway rates are frequently in force on grain not destined for export. This cannot prevent total marketing costs of grain sold on domestic markets from tending to be much less than total marketing costs involved in international trade.

On the low side, costs of marketing in the domestic markets may shrink to practically nothing, when one farmer buys

⁸ See N. Jasny, "Die Konkurrenzfähigkeit der wichtigsten Überseeländer auf dem Weizenweltmarkt," *Berichte über Landwirtschaft*, 1928, N.F., IX, Heft 1-2, 1-68.

⁹ See V. D. Wickizer, "Shipping and Freight Rates in Overseas Grain Trade," *Wheat Studies*, October 1938, XV, 116.

from a neighbor; but commonly there is little consumers' demand in the neighborhood. Marketing costs need not be high even if grain enters trade channels, provided the farmers sell and the consumers buy it in near-by wholesale markets. For example, marketing costs on grain (not including haulage to the railway station) in the province of Brandenburg, Germany, sold in carloads to mills in Berlin, are only 7 to 12 marks per metric ton; but many farmers in Brandenburg sell in lots less than carloads. In many countries, railways follow a policy of charging high per-mile rates on short distances. Where wages are high, heavy cost of loading and unloading contributes to disproportionately high marketing costs over short distances.

In large countries the upper limit of total marketing costs of grain marketed domestically approaches closely, or even exceeds, the costs on export grain. For example, the rate on grain and grain products from Indian Head, Saskatchewan, to Vancouver, British Columbia, for local delivery, is so much above the export rate that costs to Vancouver are approximately the same as to English ports. The reshipping rates from western terminal points such as Chicago and Minneapolis, to Portland, Maine, are about 6 cents per bushel of wheat higher for domestic use than for export.¹⁰ This 6 cents would take the grain almost to London. Export rates are applied in the United States on many other routes. Transportation costs from the nearest surplus regions to the intermountain regions and the southeast in the United States are rarely less, and often more, than the cost to European countries from surplus regions overseas.

Differentials on coarse grains.—With the use of data given in Appendix Note A, the cost of marketing wheat from the Canadian Prairie Provinces to English ports presented in Table 4 may be roughly adjusted to apply to coarse grains. The adjustments could be made only for grain shipped in parcels (Table 5).

¹⁰ U.S. War Department, Corps of Engineers, U.S. Army, *Transportation on the Great Lakes*, prepared by Board of Engineers for Rivers and Harbors (Transportation Series No. 1, revised 1937), p. 194.

TABLE 5.—ADDITIONAL COSTS OF SHIPPING COARSE GRAINS FROM WESTERN CANADA TO BRITISH PORTS, 1938, ABOVE THOSE SHOWN FOR WHEAT IN TABLE 4*

No. ^a	Item	Cents per unit of 60 pounds		
		Rye	Barley	Oats
1 and 3.	Handling at country and terminal elevators	0.39 ^b	1.38 ^b	4.21 ^b
4.	Lake freight	0.45 ^b	0.95 ^c	1.89 ^c
5.	Ocean freight .....	....	0.96 ^d	1.93 ^d
	Total	0.84	3.29	8.03
		Cents per cental		
		Rye	Barley	Oats
1 and 3.	Handling at country and terminal elevators	0.65	2.30	7.02
4.	Lake freight	0.75	1.58	3.15
5.	Ocean freight .....	....	1.60	3.22
	Total	1.40	5.48	13.39

* Valid only for shipments in parcels.

^a Corresponding to numbers in Table 4.

^b Increase in proportion to legal bushel weights.

^c Increase by 15 and 30 per cent on barley and oats, respectively.

^d Increase by 10 and 20 per cent on barley and oats, respectively.

As may be observed, the cost of marketing rye from western Canada to English ports exceeds the cost of wheat so little that the difference may almost be disregarded, especially as there is some saving on interest not considered in the table. But total marketing costs of barley shipped from western Canada in parcels may be higher than those on wheat by approximately 3 cents per unit of 60 pounds, and those on oats by about 7 cents. By shipping lighter grain together with heavy grain in ships chartered for full cargoes the extra cost can probably be reduced to approximately 1 cent for barley and 5 cents for oats. We do not venture to guess what proportions of barley and oats are shipped in which way.

In the United States, coarse grains are not in quite as unfavorable a position relative to wheat, with regard to marketing costs. Railway rates on these grains over several routes are 5 to 10 per cent lower than on wheat. The situa-

tion is probably relatively least unfavorable for coarse grains shipped to Europe all-rail through Atlantic ports. In this case, the total marketing costs of rye and corn may be slightly less than those of wheat, while the costs involved in marketing barley probably are only slightly higher; but total costs of marketing oats remain materially higher. If the Great Lakes are used for part of the haul, the relative position of coarse grains again becomes worse, although it remains less unfavorable than in Canada.

The situation is even more favorable or less unfavorable for coarse grains shipped from Argentina. Since Argentine railways carry corn at rates lower than for wheat, while the rate on the ocean is the same for both grains, total marketing costs are slightly less for corn than for wheat. But total marketing costs of Argentine oats exceed those of wheat, because railway rates are the same for oats and wheat while ocean transport and some handling charges on shore are more expensive for oats; the extra cost again is much less than for oats from Canada and is mostly less than for oats from the United States.

Altogether, total marketing costs in international trade are only exceptionally lower on coarse grains than on wheat, with corn and rye occupying this relatively favorable position. Barley probably at best bears the same cost as wheat, while the marketing costs on oats are always higher.

The marketing costs on feed grains which emerge after the ports in the deficit countries are reached and until the grain is in the hands of consumers are materially higher on the average than is the case of wheat and rye imported for use as food. Many mills are located in the ports of entry, so that only small additional costs (lighterage) or none are involved. Moreover, mills usually buy directly from importers or even exporters. Feed, on the other hand, always has to be carried some distance from the ports of entry to the place of use, and frequently for considerable distances. Also, one or more additional intermediaries are usually needed.

Since a great deal of grain reaches domestic markets exclusively by rail, total costs of marketing in domestic markets tend to be less unfavorable for coarse grains. Lower costs on coarse grains than on wheat occur more frequently and the extra costs, if any, are less. Still, in Canada, most of the United States, and some other countries, lighter grains have to bear higher costs than wheat.

Thus far, only those marketing costs have been considered which occur in a practically uninterrupted transfer of grain from farms to ultimate consumers. These marketing costs can be designated as costs in the narrow sense. Yet within the same hemisphere most of the grain is harvested only once a year. Storage space must be available for a large portion of the grain produced, and interest accrues on the stored portions of the production. Marketing costs which include the outlay for these additional costs can be designated as costs in the broad sense. The lesser additional outlay for interest on the stored portions of oats as compared to that borne by wheat would not suffice to cover the additional cost of providing the larger storage space needed for oats. In the case of barley, the saving on interest may balance the additional expense for storage space. Rye, however, makes a more favorable showing on the basis of marketing costs in the broad sense than on the basis of marketing costs in the narrow sense. The cost of storage is practically the same as for wheat, while the interest is less. The loss from shrinkage, if any, is of course proportionate to the value of the grain.

EFFECT ON PRICES AND PRICE RATIOS

Even where no effects of protection and of the quality of grain are present, or where they are eliminated, the observed price spreads between two different markets reflect the cost of marketing grain from one market to another to a greatly varying degree. A region may be definitely on an import basis with regard to one grain, it may be on the borderline with regard to another, and it may cover its needs fully in the re-

maining grains. The price of the first of the grains will be approximately equal to the price in the export area plus marketing costs. The price of the second grain may be all the way between this price and the price in the export market, depending on the location as to the other deficit markets and on the degree of substitution of this particular grain in production and consumption by those that are produced locally in sufficient quantities. The prices of the grains produced in surplus will be largely dependent upon the location of the region involved. The lowest limit is evidently equivalent to the price in the most profitable market to which the surplus might be shipped, less marketing costs to this market. Because deficit countries are near by, a surplus of a grain in Denmark will not lower the price of that grain to equal that in the Dakotas.

Let us see what the situation is if prices fully reflect marketing costs. The price of wheat in the Canadian Prairie Provinces on the average in the five years ending with 1936-37 was only 55 cents per bushel or 92 cents per cental. Thus the marketing costs to European mills, which amounted to about 40 cents, were equivalent to 70 per cent of the farm price or over 40 per cent of the "world market" price. In the pre-depression years the ratio between marketing costs and wheat prices was not so high as this, although the marketing costs were higher. Even then, however, marketing costs made up over 40 per cent of the farm price or nearly one-third of the price of Canadian wheat paid by the European miller. If a "normal" farm price of Canadian wheat of \$1.25 per cental is assumed, marketing costs without the cost of hauling from the farm to the shipping point exceed 50 per cent of the farm price.

With marketing costs of grains other than wheat as high as or higher than those on wheat, and their prices materially lower, marketing costs of rye, corn, feed barley, and oats add to the farm price of these grains more on a percentage basis than they add to the farm price of wheat. At farm prices of barley in the Canadian Prairie Provinces of 71 cents per

cental, in the five years ending in 1936-37, marketing costs on barley as high as those on wheat shipped to European mills almost doubled the farm price. A price advance of feed grain by 15-20 per cent from producer to consumer in regions with low prices occurs even with the distance between producer and consumer rather short and both producer and consumer selling and buying in wholesale lots.

In the countries which are continually on an import basis, i.e., where the wholesale prices of imported grain may be assumed to be above the farm prices in surplus regions by the full amount of marketing costs, *farm prices* may be either above or below the wholesale prices of imported grain, after allowance for quality differences between imported and domestic grain. Farm prices tend to be above wholesale prices, if most farmers not only do not sell that type of grain but supplement their own produce by purchases of imported grain. So far as food grain is concerned, this may happen only in those countries and regions where farmers have the grain they intend to use themselves as food ground locally. Since small custom mills are more efficient in grinding rye and corn than in milling wheat, farm prices of wheat in deficit regions are less likely to be above the wholesale prices than farm prices of rye or corn. Where farmers sell their food grain, while buying their flour, bread, and breakfast foods, only the farm prices of feed grains may be higher than the wholesale prices of imported grain.

To the extent that farmers in deficit regions or countries sell their grain, the farm price of this grain in the deficit region will tend to exceed the farm price in the economically nearest surplus region by the difference between the marketing costs of grain shipped in and those involved in marketing local grain. The more concentrated the milling industry in the deficit country or region, the larger are the distances that the local grain has to travel, and the less is the difference between the *farm prices* in the surplus and deficit regions. What is said of mills is true of any type of processor except feeders.

Thus the farm prices of food grains (including malting barley) in deficit regions tend to be higher than in surplus regions only by the difference in marketing costs from the farms in both regions to the points of location of mills, breweries, and the like; while the farm price of feed grains, when fully on an import basis, tends to exceed the farm price in the surplus region by the full amount of marketing costs from the latter. Moreover, the marketing costs from farms in the surplus countries usually are markedly higher to the farms in deficit countries than to the point of location of processing plants in such countries. The difference in the enhancement of farm prices by marketing costs between wheat (and malting barley) and the feed grains, will evidently be even larger if computed in percentages rather than in absolute figures.

Finally, in the case of two cheap grains, barley and oats, the effect of differences in the quality of locally produced grains on the price spreads between surplus and deficit regions tends to be in the same direction as the effect of marketing costs. In the case of wheat, however, differences in quality are usually an offsetting factor. Cheaper kinds of grains in deficit countries, it is true, more frequently fail to reflect in full the spread justified by marketing costs, differences in quality, and tariff duties, than is the case with wheat. This is evidenced by the fact that international trade in these grains is much less than in wheat. Hence the prices of these grains are more frequently above the shipping-out basis in regions with grain surpluses and under the shipping-in basis in regions with grain deficits, than is the case with wheat. The spread between prices of coarse grain in surplus and deficit regions nevertheless tends to be above that of wheat even in absolute figures, and still more in percentages.

The different amounts and percentages by which the grain prices in importing countries exceed the prices in export countries are obviously correspondingly reflected in the ratios between the prices of different grains at the same places, i.e., in those ratios which form the economic environment in which

the competition among different grains takes place—in consumption and for the land. The addition even of equal marketing (or other) costs to prices of different size is equivalent to a narrowing of the ratios between the prices of different grains in the same places in terms of percentages. This is schematically illustrated in Chart 19.

At a farm price of 120 cents per cental for wheat and of 80 cents per cental for corn or barley, wheat is more expensive than feed by 50 per cent. Both grains are moved to a terminal point with an expense of perhaps 30 cents per cental, and there the price of wheat is higher by only 36 per cent. The grains are then taken to an ocean port at a cost of 15 cents, and the price difference shrinks to 32 per cent. It will be only 29 per cent when the grains are brought to a harbor in Europe at a further cost of 15 cents, and will be finally reduced to 25 per cent (half of the original percentage) if the grains are transferred to some interior point at a cost of 20 cents. The narrowing of the spreads on a percentage basis is obviously still greater, if the marketing costs on feed grains, as frequently happens, are larger than the same costs on wheat.

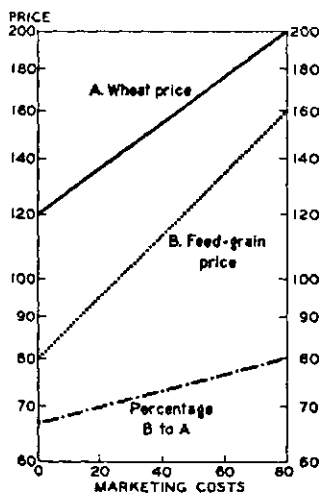


CHART 19.—SCHEMATIC PRESENTATION OF PRICE RATIOS BETWEEN WHEAT AND FEED GRAINS AS AFFECTED BY MARKETING COSTS*

(Cents per cental; logarithmic vertical scale)

* Equal marketing costs have been assumed for all grains.

Since marketing costs from surplus regions of large countries to certain deficit regions of the same countries are about as high as or higher than those from overseas surplus countries to European deficit countries, the effect of marketing costs on the geographical structure of prices within those countries may be as marked as that on the prices in different countries. Marketing costs from producers in the surplus area of eastern Germany to the deficit area of southern Germany are hardly less than from the producers in Argentina to the large markets in Great Britain. Between many places in the United States, Canada, Russia, and similar large countries, they are even larger. Correspondingly, the inter-grain ratios display unexpectedly large differences in different parts of large countries.

Interregional price spreads of the same grains.—The figures that follow represent a comparison, in cents per cental, of farm prices in the Prairie Provinces of Canada with the prices realized in Great Britain for domestic grain¹¹ on the average from 1925–26 to 1929–30, a period when prices were not yet greatly affected by government interference.

Grain	Prairie Provinces	Great Britain	Spread	
			Cents	Percentage
Wheat	175	232	57	33
Barley	107	228	121	113
Oats	125	195	70	56

Domestic wheat in Great Britain was more expensive than in the Prairie Provinces by 57 cents per cental.¹² Total marketing costs from the Canadian prairies to Great Britain may have amounted to 75–80 cents at that time. The approximately 20 cents by which the latter amount exceeded the price spread is roughly equivalent to the price spread between Canadian and British wheat in Great Britain.

British oats in the period specified brought 70 cents per

¹¹ These prices cannot have materially exceeded returns to producers.

¹² The actual difference was somewhat larger, for the yearly averages for Canadian grain are weighted by amounts, while the British prices are simple averages of monthly prices.

cental more to British farmers than did Canadian oats to the farmers in the Prairie Provinces. Marketing costs per cental of oats in those years may have amounted to 85-90 cents. Marketing costs were not fully reflected in the price spread, perhaps because prices of Canadian oats in those years were seldom at export parity. In spite of this, the spread between the British and Canadian price of oats exceeded the spread between the prices realized for wheat by 13 cents per cental, an amount which cannot be neglected.

The position of the producers of British barley was even more favorable than that of the producers of British oats. The average difference in favor of the British producer was not less than 121 cents per cental in spite of the fact that farm prices of Canadian barley were almost regularly above a shipping basis in those years. It is only natural under these conditions that on a percentage basis the additional return for British barley was equivalent to more than 100 per cent. It was still large in the case of oats (57 per cent), while British wheat brought only 33 per cent more than wheat produced far away on the Canadian prairies.

A similar comparison between prices in the Prairie Provinces and in the Netherlands, including rye, is as follows, in cents per cental:

Grain	Prairie Provinces	Groningen, Netherlands	Spread	
			Cents	Percentage
Wheat	175	212	37	21
Rye	137	175	38	28
Barley	107	180	73	68
Oats	125	170	45	36

Since the quality of rye produced in northwestern Europe is unlikely to be discriminated against as strongly as is wheat of the same origin, it would be expected that Dutch production of rye would be slightly more favored by the price situation than Dutch production of wheat, not only relatively (as it is) but also in absolute figures. The reason for the failure of Dutch rye prices to show up more favorably is probably that Canadian rye in several of those years had food value,

Dutch rye only occasionally.¹³ Moreover, wheat in the Netherlands is regularly a deficit product, while deficits of rye occur only from time to time.

As in Great Britain, the spread between Canadian and Dutch prices was greatest in the case of barley and oats, although the advantage of Dutch barley was much less striking than that of British barley. On a percentage basis, Dutch barley prices exceeded those in the Prairie Provinces by 68 per cent, while the spread between wheat prices amounted to only 21. Dutch oats and rye occupied intermediate positions with spreads of 36 and 28 per cent, respectively.

For corn we do not possess prices in an importing country suitable for a similar comparison. In the years specified, corn production was protected by tariffs in all the European importing countries producing it. But the fundamental changes in the competing power of the more expensive and the cheaper grains brought about by the approximately equal marketing costs is clearly revealed by a comparison of prices in surplus and deficit regions of the same country. The following figures are average farm prices in the states of Iowa and New York, in cents per cental, from 1925-26 to 1929-30:

Grain	Iowa	New York	Spread	
			Cents	Percentage
Wheat	197	226	29	15
Rye	148	180	32	21
Barley	123	167	44	36
Oats	122	172	50	41
Corn	130	182	52	40

While wheat in New York state was more expensive than in Iowa by 29 cents and 15 per cent, the difference in corn was equivalent to 52 cents and 40 per cent. New York prices of oats and barley also exceeded the Iowa prices of these grains by much larger margins than was the case with wheat. Even rye showed a somewhat larger spread, both in cents and percentages.

¹³ Dutch rye prices averaged only 3 per cent above those of oats.

Inter-grain price spreads at the same places.—With some exceptions—as for example the period 1925–29, particularly favorable for rye—prices of coarse grains to producers in the Canadian Prairie Provinces tended to equal about 65 to 70 per cent of wheat prices in postwar years, even though only Canadian wheat was regularly on an export basis during the periods specified. The other grains were exported in some years and not in others. Even in the years when exports of coarse grains were made, their prices were often above parity for months. Moreover, only parts of the Prairie Provinces ship coarse grains; others produce for home use exclusively and have prices above the shipping-out parities which nevertheless are used in computing averages.

Although wheat was continuously and everywhere in the grain belt on a shipping basis and coarse grains were not, the ratios of the prices of coarse grains to those of wheat at the head of the Lakes¹⁴ tend to be higher than on the prairies. In periods used in Charts 2 to 4 the ratios were as follows:

Grain	1925–26 to 1929–30		1932–33 to 1936–37	
	Prairie Provinces	Winnipeg	Prairie Provinces	Winnipeg
Wheat	100	100	100	100
Rye	78	80	72	78
Barley	61	69	77	73
Oats	71	80	69	87

The only ratio which failed to be higher in Winnipeg than in the Prairie Provinces was the ratio between barley and wheat prices in the second period, distinguished by particularly low average yields of barley. If the prices for the Prairie Provinces and Winnipeg referred to the same qualities, the ratios of the prices of rye and barley to those of wheat in Winnipeg would have been even higher relative to those in the Prairie Provinces than is shown by the data in the tabulation, but the difference in the ratios of oat prices would be less.¹⁵

¹⁴ The prices quoted at Winnipeg are for grains in store at Fort William–Port Arthur.

¹⁵ No. 3 Manitoba wheat, to which the Winnipeg price applies, is slightly below the weighted average of all grades on which the farm prices are based. No. 2 rye and No. 3 barley are probably approximately equal to the average of all grades, while No. 2 oats are materially above the average.

No farm prices are available for Argentina, the only country which now more or less persistently exports all five grains. In Buenos Aires, whose location with reference to the import markets of western Europe approximately corresponds to that of Fort William-Port Arthur or Chicago, coarse grain prices in 1932-36 usually averaged a little less than 70 per cent of wheat prices (Chart 2, p. 10). On a farm basis, the corresponding figure would probably be somewhat less than two-thirds for oats and rye and about two-thirds for corn and barley. These ratios are very similar to those observed in the Prairie Provinces. So far as barley and oats are concerned, this similarity is the result of compensating factors. The smaller total marketing costs on Argentine grain tend to make the ratios more favorable for coarse grains in Argentina than in western Canada. But the moderate quality of the Argentine grains seems to affect the returns for barley and oats more than those for wheat.

The prices in the Danubian harbors and Odessa given in Chart 2 also indicate prices of coarse grains to producers equivalent to three-fifths to two-thirds of wheat prices. These ratios may be regarded as typical for surplus regions located far from import markets. But to yield these ratios the market must be on an export basis for both wheat and coarse grains. In Punjab, British India, for example, the spreads between the prices to producers¹⁶ of barley and wheat (on a percentage basis) are narrower than this, because wheat prices on the average are substantially nearer to an export basis than are prices of barley. The low quality of the Indian wheat may also be a factor (see p. 123).

The price ratios of coarse grains to wheat in Budapest, Hungary, are materially higher than in Buenos Aires or in the Rumanian ports, owing both to a more favorable location as to deficit markets and to the fact that large surpluses are available only in wheat.

The price ratios in North Dakota in postwar years have

¹⁶ The source used describes the prices as "harvest prices."

been among the widest, owing to high premiums often paid for hard spring wheat and sometimes also for durum produced there—in part an effect of United States import duties. Barley and oats, and in recent years rye also, are the grains which are particularly cheap relative to wheat. Corn is not a surplus crop in North Dakota. The farm prices of coarse grains in Iowa make a more favorable showing relative to the prices of wheat, owing to the facts that Iowa wheat is by no means a premium wheat and that no surplus of either rye or barley is available. Farm prices in New York clearly reflect the strong effect of marketing costs in narrowing the spread between the prices of wheat and coarse grains on a percentage basis, although the poor quality of New York wheat is also a factor (Chart 2, p. 10).¹⁷

Both in the prewar and postwar predepression five-year periods of prosperity, world market prices of imported feed barley and oats tended to be equivalent to approximately three-quarters of the price of imported wheat. The spread between rye and wheat prices was still narrower, while the spread between corn and wheat prices was somewhat wider (see "world market" prices in Chart 3, p. 11). The narrowing of these ratios as compared with those in exporting countries is comparatively small because the prices in most export countries are more frequently on an export basis for wheat than for coarse grains. For example—with the price ratios usual in the Canadian Prairie Provinces—in order that all Canadian grains be continuously shipped to Europe, the world market prices of rye and barley would have to be equivalent to 80–85 per cent of the world market wheat price, and those of oats to 85–90 per cent of the latter. Since the spreads on the world market are not so narrow, Canada can export wheat almost every day, but the exports of other small grains are possible only more or less occasionally.

Substitute now, for the prices of imported grains, the prices

¹⁷ A strict subdivision of regions and countries among Charts 2, 3, and 4 would require placing the farm prices in New York in Chart 3. They are included in Chart 2 largely owing to considerations of space.

of the same grains produced in the importing countries of northwestern or north central Europe, with a relation in quality considerably more favorable for barley and oats than for wheat. Consider furthermore that farmers in those countries frequently buy feed grains and sell wheat, and the closeness of the prices of coarse grains to those of wheat observed in the duty-free countries of northwestern Europe is explained in full. As shown in Chart 3, in Great Britain, the Netherlands, and Denmark, which did not have import duties before the depression, prices of domestic coarse grains were not less than four-fifths of the prices of domestic wheat. The prices of domestic oats and rye, in fact, were roughly equivalent to five-sixths of the wheat price, and the prices of barley¹⁹ and wheat were still closer together. The average barley prices, in fact, were so close to wheat prices that malting barley alone evidently averaged more than wheat.

EFFECT ON CONSUMPTION

Marketing costs affect consumption (and production) of each grain both directly and indirectly. The indirect effect is the result of the effect of marketing costs on total consumption (and production) of grain. The direct effect is exerted in two different ways: (1) through the tendency of grain to be used on the spot, and (2) by way of the approximately equal marketing costs.

The effect of marketing costs on total consumption of all grains is toward contraction, but is usually small so far as bread grains are concerned. Where the standard of living is low, the enhancement of grain prices through marketing costs may be an additional reason for using more potatoes and similar cheap carbohydrates. On the whole, however, the consumption of bread grains in a predominant part of the world is largely independent of production costs, marketing costs, and the like, the main issues being in the distribution of the total between different grains and different countries.

¹⁹ The prices of barley for those countries are averages for all domestic barley including malting barley.

The effect of marketing costs on the total amounts of grains used for feed is more substantial than on the amounts used for food. In many grain-surplus regions the principal feeds are grain and residuals of grain production; but in regions which bring in grain over long distances, or would have to bring it in, the expensive grain is reduced to the role of a concentrate supplement and as little is used as is consistent with rational feeding. Marketing costs are of course only one reason for this difference—and mostly a minor one—and the animals for which grain becomes a concentrate supplement are primarily ruminants, although many hogs also are raised almost without grain.

By what kinds of feed is grain replaced in the role of the principal feed in such deficit regions depends primarily on the wage level. Higher wages stimulate the use of types of feed which require relatively small amounts of labor. In the northeastern United States, pasture and hay represent the principal feed. In western and central Europe, with its lower wage level, immense amounts of beets and potatoes are produced and fed.¹⁹

Consumers of rye bread on the average are poorer than consumers of wheat bread. Thus, so far as marketing costs reduce consumption of food grains at all, they are likely to affect the consumption of rye more than that of wheat. As to feed grains, the grains affected depend on the type of products for which the grains are used. In importing countries (but also in Poland and some other intermediate countries) a large proportion of hogs is raised on potatoes, a substitute for barley and corn, while feed beets are fed mostly to cattle and are primarily a substitute for oats and corn.

Since marketing even within the same region frequently involves rather substantial costs relative to the farm price, marketing costs give a strong stimulus toward the use of the

¹⁹ There are, however, opposing tendencies. Beef and mutton imported by European countries from overseas (originating mostly in Argentina, Australia, and New Zealand) are produced practically without grain, whereas some grain is used in the production of the same products in the importing countries.

grain in the region, or even on the farm, where it is produced. The marketing costs on grain and flour, which the farmer would have to bear if he sold the bread grain and bought the flour needed for his own use, both the grain and flour traveling some distance, are too high to be readily offset by the saving attained by large-scale flour production. Hence, except in countries with high wages, the milling industry is so decentralized that the farmer has the opportunity of taking his grain directly to a local mill and of having it ground there into, or exchanged for, flour. In a very small degree this opportunity is available even in countries with high wages.

The incentive to use grain on the farm where it is produced is even more important with regard to the grain that is utilized as feed. Efficient feeding does not require large size of individual plants as in milling, brewing, or the production of starch and syrup. Moreover, the weight of the animal products that are produced (except, in some cases, milk) is much less than the weight of the feeds used to produce them. Hence, feeding takes place most conveniently on the farm even with regard to such animals as hogs, for which the feed consists almost exclusively of protein supplements (frequently brought to the farm from the outside) and grain. Where large amounts of bulky feeds are used, the feeding is definitely bound to the farm.²⁰

The inducement to use the kind of grain available on the spot is so strong that it materially affects the selection of the grains consumed. In many surplus regions producing wheat but no rye, consumers would save little if the wheat were shipped out of the region and rye or rye flour shipped in. On the contrary, shipping out rye and buying wheat from another region involve a much larger sacrifice for the consumers

²⁰ So far as part of the feed has to be brought to the farm, it is not the bulky feed but the grain that is relatively expensive and can more easily bear the cost of transportation. The feed grains shipped to the northeastern United States and to eastern Canada are supplementary to the hay and pasture produced by the local farmers. The situation in the importing countries of western Europe is the same, except that locally produced beets and/or potatoes are available along with hay, straw, and pasture.

in some rye regions than that borne by consumers located in places where the prices of rye and wheat are about equally affected by marketing costs. The inducement to use the available kind of bread grain is particularly strong with regard to farmers who grow grain themselves, notably in surplus regions producing only one kind of bread grain and possessing the opportunity of having their grain milled into flour in a neighboring mill. But the double marketing costs materially affect the bread consumption of farmers even in deficit regions, provided a mill for custom work is available near by. The situation is similar where grains other than rye compete with wheat as a foodstuff.

Feeding a kind of grain not well adapted to a particular use, merely because this grain is available in greater quantities in a particular region or on a particular farm, is much more widespread and important than the use of a particular bread grain under similar conditions, owing to the much greater readiness of the consumers to substitute one feed for another than one food for another. For example, the desire to avoid marketing costs is the principal reason for the large use of barley as horse feed in many regions.

Particularly hampered by high marketing costs, and therefore extremely rare, is the sale by farmers of a certain kind of feed grain and the buying of another kind better adapted to a particular need. To a much larger extent there is adjustment of animal industry to the particular conditions of different crop-producing regions and farms. Marketing costs are avoided by selecting those branches of animal husbandry which can best utilize the feed, or the combination of feeds, produced in particular regions or on particular farms. Regions especially adapted to grass and oats produce milk; regions particularly adapted to corn produce beef and pork; regions adapted only to potatoes, rye, and oats are limited to the production of pork.

Of the two bread grains, rye undoubtedly is the gainer from the tendency of the grains to be used on the spot. Much

rye would not be consumed unless it were produced by the consumers themselves or in the same region. Of the feed grains, oats—the feed grain most widely produced in regions with the densest livestock populations—gain most from that tendency. Corn on the other hand, which is not produced in Europe's most important livestock regions and is the strongest competitor on the world markets for feed grains, is the greatest loser from the same tendency.

On the other hand, in deficit regions marketing costs stimulate food consumption of wheat at the expense of rye (and other cheap food grains); because rye prices are increased by marketing costs relatively more than wheat prices. But this effect can be observed only in regions which produce no grain or are unadapted to the production of rye. In deficit regions adapted to rye production, this is fostered by the equal marketing costs on wheat and rye; enlarged production of rye leads to its greater consumption, and the opposite direct effect of marketing costs is more than offset. We discuss these entanglements in the next section.

EFFECT ON PRODUCTION

As with consumption, it is useful to distinguish between the indirect and direct effect of marketing costs on the production of each grain.

The indirect effect is through the effects of marketing costs on the total production of grains. While marketing costs in deficit regions exert a contracting effect on grain consumption, the effect on grain production there is naturally in the opposite direction. It is probable, moreover, that the effect on production is stronger than on consumption. Prices enhanced by marketing costs bring about the use of soils for grain production which would not be so used if located in a surplus region. Throughout southeastern and northeastern United States, grain is produced on soils many of which would be used only for pasture if located in a surplus region. In many European deficit countries, considerable stretches of land are

put into grain which would not be used even as pasture if located in a surplus region. Mountain people grow grain on slopes which seem inaccessible to people from the plains.

Marketing costs, it is true, do not necessarily involve increased grain acreages in deficit regions. On the contrary, since the cost of marketing roughage in relation to its cost at the farm is much larger than that of grain, it is frequently more profitable for deficit regions and countries to concentrate on the production of roughage, relying on shipments from surplus regions for the needed grain. The major effect of marketing costs on the production of grains is that, so far as acreage is devoted to them, the higher prices make profitable production by more intensive methods. By painstaking cultivation and heavy application of manure and commercial fertilizer, yields have been raised greatly in many deficit countries. Land of a quality which is left unused in sparsely populated surplus countries has been made to yield more heavily than good land in surplus regions. Where grain acreage has not been cut down substantially more than intensive methods of production necessitated,²¹ total grain production of importing countries has increased far beyond what could have been attained by extensive methods.

The extent to which each grain participates in these increased yields depends on its ability to retain or attain a share of the acreage in regions with the large yields, and there are great differences among them in this respect.

Let us now turn to the direct effect of marketing costs on the competition among grains for a place in production. In order to avoid marketing costs by using the grain where it is produced, consumption shifts from one grain to another. Shifts in production operate in the same direction. It will be shown in Part III that the advantages or disadvantages of producing one kind of grain rather than another are frequently very narrow. Time and again these advantages are

²¹ Intensive agriculture compels use of a materially smaller portion of the total crop acreage for grain than is common in extensive agriculture.

outweighed by additional marketing costs. It may be profitable to produce a particular kind of grain on the spot because this particular kind is needed, while it might not be profitable to produce it if it had to be shipped out. Although much barley is fed to horses because it is at hand, large quantities of oats are produced only because the farmers keep horses; and substitution of tractors for horses promptly puts an end to such production.

The approximately equal marketing costs of the different grains encourage the production of cheaper grains in deficit or prospectively deficit regions much more than the production of expensive grains. The magnitude of this effect seems not to be commonly realized. Oats and barley have a greater yielding capacity than wheat, with corn the really heavy yielder (pp. 197-203). The increase in the return from the production of the grains with higher yields that is possible under the protection of marketing costs is obviously larger than the increase in the return from the production of grains with lower yields. Thus, 15 centals of corn at 80 cents bring a smaller return per acre than 10 centals of wheat at \$1.25 (\$12.00 as against \$12.50). With a protection of equal marketing costs of 50 cents per cental, the same yields result in a substantially larger return from corn (\$19.50 as against \$17.50). But the marketing costs on oats are even larger than those on wheat, and for barley and oats the effect of the marketing costs is reinforced by the effect of the quality factor, which acts in the same direction.

Wheat production is mainly concentrated on the drier fringes of agricultural cultivation, though in many of these regions its disadvantage in yield and cost of production is materially larger than on intensively cultivated better lands in deficit regions. The lesser ability of cheaper grains to bear high marketing costs, and the beneficial effect of drier climate on the quality of wheat, more than offset the unfavorable position of wheat with regard to the cost of production in such regions.

The competition of coarse grains with wheat for the land is especially strong where, as with oats and barley, the effect of marketing costs is greatly reinforced by the beneficial effect of drier climate on the quality of wheat and its deteriorating effect on the quality of coarse grains. But the power of coarse grains to compete with wheat for the land is enlarged materially even where the reinforcing effect of the quality factor is much less. The quality of corn does not show material variations between regions, and the wheat of the principal corn surplus regions commands relatively small premiums over wheat of the principal deficit countries. Yet the greater support to corn from marketing costs and the lesser desirability of wheat of deficit regions prove sufficiently strong in their effect on corn production in deficit countries to offset the effect of another pertinent factor operating in the opposite direction, namely, that the intensive methods of crop production followed in deficit countries greatly reduce the advantage of corn over wheat in cost of production.

With rye, marketing costs receive the smallest support from the quality factor, in their influence on the competition of different grains for acreage. The quality of rye also is impaired in moister climates, though not so strongly as that of wheat. Moreover, the depressing effect of marketing costs on consumption of rye exceeds that of wheat. Rye nevertheless is often the chief beneficiary from the stimulating effect of marketing costs on grain production in deficit regions. The advantage in the field is considerably more important for rye than the disadvantage in the dining room. Owing to the tendency to use the kind of grain that is available on the spot, consumption of rye bread, in regions where production of rye is kept up by marketing costs, is also kept at a higher level than it otherwise would be.

EFFECT ON TRADE

The stimulating effect of marketing costs on grain production in deficit regions and its contracting effect on grain

consumption are necessarily reflected in the grain trade. The effect of marketing costs on bread-grain consumption in deficit regions has been accepted as only slight. Furthermore, production of one kind of bread grain only—rye—is strongly stimulated by marketing costs. With regard to wheat, marketing costs still leave plenty of room for big deficits, and deficits make possible surpluses somewhere else.

The development of large deficits of feed grains in deficit regions (or countries) is hampered both by the contracting effect of marketing costs on the use of grains for feed, and by the fact that the production of feed grains (and rye, a large portion of which is also used as feed in those regions) is encouraged by marketing costs more than is production of wheat. International and interregional trade in corn, the strongest competitor on the world markets for feed grains, must inevitably lose from the fact that high marketing costs tend to hamper the development of large deficits of feed grains.

Particularly inhibited by marketing costs is the shipping out of one kind of grain from, and the shipping in of some other grain into, the same region or country from a distant region or country. Surpluses or deficits of one kind of grain, in a country or region having a material deficit or surplus of grain in general, are mostly prevented by shifts in consumption, production, or both. Hence grain is not much shipped to regions having deficits of some grains only while having surpluses of some other grain, but mainly to such regions as have a deficit in grains generally, and vice versa.

The few exceptions that are found in international trade involve mostly wheat or malting barley, two of the three grains which are not readily replaced in consumption. California, deficient in several grains, exports large quantities of malting barley. The Union of South Africa for many years imported wheat while exporting large quantities of corn.

With regard to the third of these grains, rye, it would be necessary to go far back into history to find more than rare

examples of its importation or exportation in large quantities while some other grain was exported or imported. It is true that, during several prewar and some postwar years, Germany exported large quantities of rye (and oats) while importing huge quantities of other grains. But this situation is explained by the exceptional combination of import duties on rye and oats higher than on corn and barley, the system of export certificates, and the location of Germany's surplus and deficit regions. The long-run trend toward contraction of the consumption of rye bread means that rye is more and more unable to overcome the handicap of marketing costs but, on the contrary, must rely on the protection of marketing costs (and/or tariffs) in order to preserve the remnants of its position as a bread grain.

MARKETING COSTS IN THE PAST

The great significance of the modern technique of transportation for the market of cheap goods like grain is too well known to be dwelt on at any length. Before the advent of steam transportation, only countries and regions well supplied with waterways could ship out or ship in large quantities of grain. Hauling by wagon, particularly on the primitive roads of earlier days, was not suitable for long-distance transportation. On primitive roads, 150 miles is a long distance; on a round trip of approximately 350 miles each way, horses will have eaten the whole load.²² Yet conti-

²² Where there are no modern means of transportation, the situation remains what it was a century ago. The following is adapted from the description of the situation in a very remote Lepsin district, government of Semiretchensk, Turkestan, in an extensive study of the cost of production of grains in Russia immediately before the World War, made by the Russian Ministry of Agriculture (*Cost of Producing Principal Grains in 1916* [translated title], Petrograd, 1916, II, 895-96). Distances to market places: Sergiopol, 225 miles; Karkalinsk, 450 miles. Cost of hauling: 40 cents per 100 pounds to Sergiopol; 70-80 cents to Karkalinsk. Very good land yields high, but there is no market, owing to the absence of railways in the district. Wheat rarely costs more than 40 cents per bushel, usually 16-20 cents. A little flour is hauled in the winter to Sergiopol and sold there at from \$1.65 to \$2.65 per barrel. In the spring they take it by oxen (evidently pasturing them on the way as was done a century earlier in the Ukraine) to Karkalinsk and sell it there at \$2.20 to \$3.30 per barrel. In general, grain is produced for local needs only in the smallest quantities. While such was the situation with wheat, coarse grains obviously would not have paid the transport.

mental regions poorly supplied with waterways were best adapted to the production of wheat and most other grains for export. Regions now supplying almost all the wheat entering the international trade, and a substantial proportion of coarse grains, were uninhabited before the steam era, and could have been inhabited only on a self-sufficing basis.

Steam was not quite so revolutionary in ocean as in land transportation. A few sailing vessels still cross the oceans on routes with favorable wind conditions. Oddly enough, it is the route from Australia, the longest one used in the grain trade, on which some wheat still arrives in Europe by sailers. But sailing also has been modernized in recent times. Moreover, lacking the supplies from remote continental regions, the international grain trade could not have been large before the railway era, even if sailers had provided an efficient service on the water. In fact, international trade in grains was practically limited to the countries adjacent to the North and Baltic seas before the nineteenth century, while in the Roman world the Mediterranean Sea was the Atlantic, Pacific, and Indian oceans, all in one.

CHAPTER VII

PROTECTIONIST MEASURES

Protectionist measures, like costs of marketing between surplus and deficit countries, raise the levels of grain prices more or less substantially and therefore materially affect consumption, production, and trade in grain. But whereas marketing costs on all grains are about equal, with the consequence that the cheaper grains necessarily are more affected than the expensive ones, the amount of protection given to different grains shows all imaginable variations with similarly divergent effects.

Duties are mostly piled on top of marketing costs. This "top" nowadays, it is true, has in many countries become so large that the thing under it is almost invisible; and the danger of overlooking the effects of marketing costs on the competition between different grains makes it even more necessary to stress them. But discussion of the effects of protectionist measures can be restricted to specific aspects.

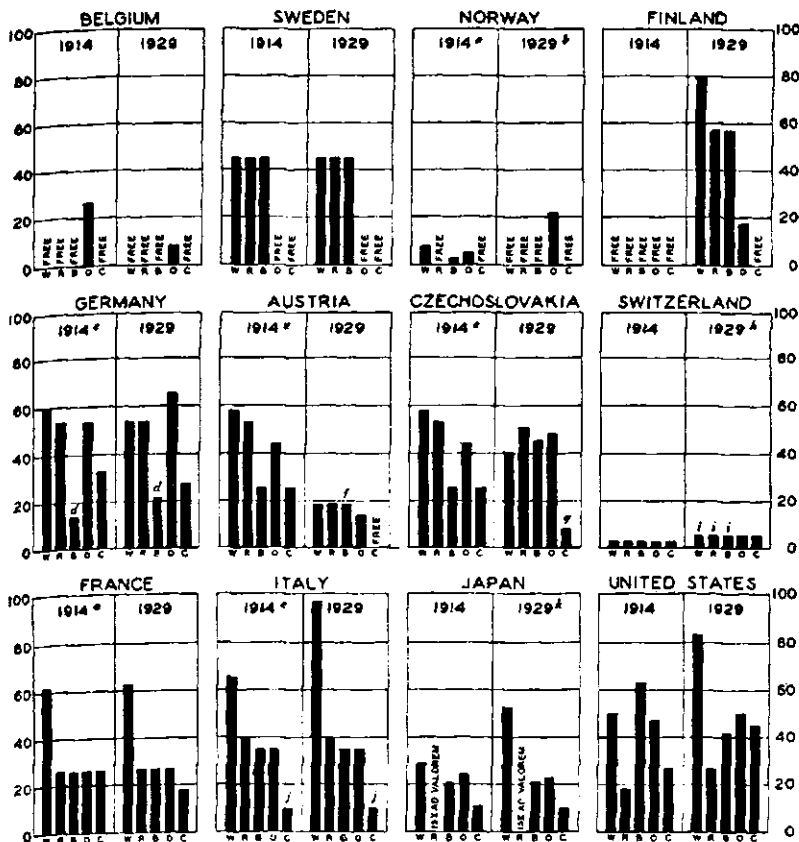
PROTECTION IN GENERAL

In prewar years four European importing countries admitted all grains free of duty, but only one, the United Kingdom, was a very large importer. The others were the Netherlands, Denmark, and Finland. To this list three others may be rightfully added (see Chart 20). In Belgium, all grains except oats were on the free list. In Norway, wheat, barley, and oats were dutiable, but the duties were low. In Switzerland, duties were imposed on all grains but were very small. On the other hand, all countries in continental Europe with large grain deficits (Germany, France, and Italy) and some others imposed duties rightly considered high at that time; the average level of these may have been rather close to the total marketing costs from important export countries overseas.¹

¹ The average level of import duties is rather difficult to ascertain. It cannot be determined simply by averaging the duties, because the duties on one grain greatly affect the protection given to other grains, particularly feed grains (pp. 178-81).

CHART 20.—IMPORT DUTIES ON GRAINS IN SPECIFIED COUNTRIES, AS OF JANUARY 1, 1914 AND 1929*

(Cents per cental)



* Based on data mainly as compiled by Miss Mary A. Malamphy, Foreign Agricultural Service Division, Bureau of Agricultural Economics, U.S. Department of Agriculture; for a few countries, on data supplied by Miss Roberta P. Wakefield, Division of Foreign Tariffs, U.S. Department of Commerce. To these the writer is greatly indebted for this material.

^a Minimum tariff.

^b Imports under special conditions. Government monopoly.

^c Conventional tariff.

^d Duty on feed barley; other barley 43.2 and 54.0 cents per cental in 1914 and 1929 respectively.

^e Conventional tariff of former Austro-Hungary.

^f Other than feed barley; feed barley exempt from duty.

^g For feeding purposes; other corn 24.2 cents per cental.

^h All imports subject to internal regulations.

ⁱ Does not include supplementary tax to be paid on imports not subject to internal regulations.

^j Yellow corn; white corn has the same duty as wheat.

^k Limitations on imports.

The effect of the tariffs on prices, like the effect of marketing costs, ranged from nil to practically full, depending on the size of the deficit, ease of substitution, and the like. By a system of export certificates, Germany assured an approximately full effect of the tariff on all grains, even those produced in excess of domestic requirements.²

Chart 18 (p. 137) shows that in the large importing countries of continental Europe the effect of the prewar tariffs was sufficient to bring the prices in those countries to the highest of the arrays. Witness the order of average prices of wheat in 1909-13, for example, reading from the highest (solid bars): Italy, 254 cents per cental; Vienna, Austria, 243; Paris, France, 236; Budapest, Hungary (at that time enjoying the protection of the Austro-Hungarian tariff), 224; the province of Brandenburg, Germany, 221 cents per cental; and so on. The Netherlands, Great Britain, and Belgium, with wheat prices equivalent to 167, 169, and 178, are found in the list well above the protectionist countries. As to rye prices, the end group contains the same countries as in the case of wheat, with the small difference that Brandenburg, Germany, is third from the end and Budapest fourth.

After a period of transitory regulation during the World War (when many more countries placed grains on the free list) and immediately ensuing years, the prewar situation with regard to protection of domestic grain production was by and large reestablished. With a few exceptions, countries which had no import duties before the war continued in this path.

² Certificates (*Einfuhrscheine*) could be obtained in Germany against exports of any grain, either imported or domestic; they permitted duty-free import of an equal amount of the same grain or an amount of any other grain or of some other specified commodities the import duties on which were equal to that which would be charged on the exported grain if it were imported rather than exported. This arrangement brought it about that German prices could not be less than the full amount of duty above the prices in neighboring countries which were in a supply situation similar to that of Germany. But conversion of a certain grain from a deficit one into a surplus one, while not depriving the grain of the full protection of the tariff, brought about a certain loss in the protection of marketing costs. This loss was relatively small in Germany, however, since the principal German surplus regions were economically nearer to deficit countries than to German deficit regions. See N. Jasny, *Die Zukunft des Roggens* (Vierteljahrshefte zur Konjunkturforschung, Sonderheft 20, 1930), p. 65.

Import duties of the protectionist countries were mostly restored to about the prewar level. Since import prices of grains were materially above those of the latest prewar years, the general level of protection was less. It was, however, still high enough to ensure that, with few exceptions, the protectionist countries stood at the bottom of the arrays of average prices arranged from lowest to highest (Chart 18).

In the unprecedented collapse of the world grain markets during the depression beginning in 1929, there was not a single importing country which did not attempt to protect its grain producers from bankruptcy or at least unbearable decline in the standard of living. Tariffs were raised in many countries to unprecedented levels, in some cases becoming the equivalent of import prohibitions. The tariff on wheat, for example, on January 1, 1938 was 71.7, 87.4, and 150.6 cents per bushel in Czechoslovakia, France, and Austria, respectively, and Germany's regular duty was even 383.7 cents. It is no wonder that not a pound of wheat has been imported into Germany with payment of the regular duty in years. So far as tariffs did not become prohibitory, several were made flexible for the purpose of ensuring domestic producers some minimum price, usually a rather high one.

Moreover, before the recent depression tariffs were almost the only instrument of protection, except in wartime. Measures other than import duties have increasingly become the principal forms of protection; and price guarantees, fixed or minimum prices on domestic or all grains, compulsory admixture of domestic to imported grain (especially milling quotas), import quotas in all possible forms, grain monopolies of various types—frequently a whole battery of such measures applied simultaneously—have come to take over the previous functions of the relatively moderate, fixed import duties. For example, several countries, including Eire and Belgium, imposed no import duties or only small ones, but made imports dependent upon licenses. Only those importers were licensed who made payments to certain funds or, more frequently,

bought a prescribed proportion of their requirements from domestic producers at prices (mostly prescribed) much higher than the prices of imported grain.

Under such conditions small import duties, or the absence of any, give no indication of the real amount of protection bestowed upon domestic producers. It therefore seemed fruitless to show in Chart 20 the present duties side by side with the duties for the two earlier periods which fulfill this role with a fair degree of accuracy. To get a more or less precise idea of the present-day protection, analysis country by country would be necessary, but limits of space preclude it. We have to be content with a few remarks.

Protection of domestic grain production in importing countries, as introduced during the recent depression, on the whole vastly exceeded everything known in the past. Only a few of these measures were discontinued after the acute emergency had passed, and in 1938 and 1939 some of the barriers were again raised; but great differences in degree can be observed.

The world for years has suffered from large overproduction of wheat. Unprotected prices, as illustrated by world market prices, have been much less than the prewar ones, both in United States currency and as deflated by wholesale-price indexes. Yet in some importing countries, the powerful weapon forged for the protection of the domestic grain has been used to such an extent that prices not only did not fall below the predepression level but even exceeded it in terms of wholesale-price indexes. All three large deficit countries on the European continent have even kept their grain prices at the full level of the last prewar years—a level extremely favorable to their producers because world-market prices of those years were good and domestic prices were considerably enhanced by the high tariffs. Wheat at Milan in 1938 averaged five times the price of 1909–13, while the wholesale-price index exceeded that of 1913 only 4.85 times. The German wheat price in the same year averaged slightly lower (wheat price 1.5 per cent above prewar, wholesale-price index 5.7

per cent above), but the 1938 rye price averaged 17 per cent above the prewar price. The French wheat price in 1938 averaged 7.45 times the prewar price, with the wholesale-price index only 6.35 times as high as prewar.

On the other hand, several countries—among them most of those formerly without import duties—limited their protectionist activities to mitigating for their producers the terrific disturbances of the international grain market.

The calamity of the collapse of grain prices on world markets was so great that, since the onset of the recent depression, contrary to the previous practice, almost every exporting country also felt impelled to embark on price support by extraordinary measures, although this was technically much more difficult than in importing countries. Import duties could obviously have little if any effect, except when an exporting country temporarily shifted to an import basis—as happened in the United States—or when supplementary measures reinforced their influences. Export premiums—frequently financed by having the domestic consumers pay a much higher price than was attainable on foreign markets—became one of the favorite devices. There is no occasion here to review in detail the manifold measures used in exporting countries. Let us state however, that exporting countries, like the former duty-free importing countries, have mostly been more moderate in their price-raising efforts, many of which, moreover, were rather unsuccessful.

With prices in some importing countries exorbitantly raised by protection over the level of world market prices and prices in exporting countries enlarged only moderately by protection or not at all, the *range* of prices of the same grains in different markets in recent years has reached proportions far in excess of those observed in peace time since the development of modern means of transportation. Uncertainties with regard to the rates of exchange which should be used in converting prices to a uniform currency have impelled the writer to abstain from offering arrays of recent prices in

different countries similar to those presented for the periods 1909-13 and 1925-29 in Chart 18 (p. 137). Converted at the official rate of exchange, the price of wheat in Italy in May 1938 exceeded the price in Melbourne by 168 per cent, while in 1909-13 the difference amounted to 59 per cent only.

Effect on production, consumption, and trade.—It was stated that the major effect of import duties is to add to the influence of marketing costs on consumption, production, and trade. Although most import duties were not reflected to their full extent in the prices of the protected areas, their effect on consumption and production of the protected areas and on international trade—on top of marketing costs—was very large even in prewar years of relatively moderate protection. While unprotected grain production in the United Kingdom shrank greatly after the development of overseas competition in the second half of the nineteenth century, production was much expanded in protectionist France and Germany. In fact, the effect of the tariffs in those countries was so great that it not only retarded the reduction in the proportion of acreage devoted to grain (which would be a natural development for agriculture rapidly shifting to more intensive methods of production), but in Germany it even brought about an increase in acreage under grains from 55.4 per cent of the total arable land in 1883 to 59.1 per cent in 1913.

The effect of tariffs on grain consumption in the protected countries was obviously similar to that of marketing costs. For example, the inducement to shift to bulky feedstuffs yielding heavily per acre has been strengthened even more than by marketing costs alone. As consumption was hampered and production stimulated, import requirements were simultaneously cut from both directions. *Ceteris paribus*, the inevitable contraction in imports was much larger in feed than in food grains.

Developments in production technique, and especially of the fertilizer industry, were such that the smaller protection (on a percentage basis) in earlier postwar years was enough

to exert approximately as strong an effect on production as that attained before the war. Since the contracting effect of protection on consumption continued and since, moreover, it found strong support in the much slower growth of population, international trade in grain showed signs of having approached, or even entered, a downward trend even prior to the recent depression.

The extreme protective measures of the recent period prevented adjustment of consumption or production in the importing countries, taken as a whole, to the ample supplies of grains that became available in the world. Several countries indeed increased their production and contracted their consumption by such measures which would be justified only if a great scarcity of foreign supplies prevailed. High tariffs, which in some countries are altered in the direction opposite to price changes in exporting countries, as well as quantitative limitations of imports, preclude also the normal reaction of importing countries and of international trade generally to short-time changes in surpluses of exporting countries and prices in world markets.

PROTECTION OF INDIVIDUAL GRAINS

Thus far we have considered the effects of tariffs on consumption, production, and trade in all grains together. Competition among the several grains would have been affected by protective policies even if all grains had received equal protection.³ The prices of different grains in the protected and unprotected areas could not be raised or lowered by protectionist measures in the same proportions, i.e., the ratios between grain prices could not but be altered in both kinds of areas. Moreover, equal protection is rarely found in practice. But the proportions of different grains produced in the world would not remain the same, even if such a proportion-

³ It is unnecessary here to define precisely "equal protection." Equal percentage price-support rather than equal protection per unit of weight seems to us the best concept.

ality could be attained. For grains are produced in different proportions in countries which, owing to tariffs, increase their production and in those which are thereby forced to reduce theirs or increase it less than they otherwise would. Particularly since the depression, many countries have been converted into separate "worlds," in each of which the grains fight out their particular battles. Neither world production nor its distribution between the individual grains, as they emerge from numerous victories and defeats in secluded territories, can be expected to be the same as in a world free or reasonably free of trade barriers.

As with world production, the international trade in each grain would be affected quite differently by the protective policies, even if all grains received equal protection. Corn would suffer most. It is not produced or is produced only in moderate quantities in the protected territories, and it dominates the world trade in feed grains. Even with equal tariff protection, corn production is likely to expand least in the protected countries taken as a whole, while expansion of corn production in surplus countries is hampered most by contraction in the volume of international trade in feed grains.

But protection of different grains is not necessarily equal, and food grains (especially wheat) and feed grains differ materially with reference to their response to unequal protection. This difference is caused by the different elasticities of the demand and especially by differences in the extent of substitution of one grain by another. The much smaller elasticity of demand for food grains makes it an easier task to protect their production by government measures.

For the volume of production of wheat (or of any other grain) in the protected areas, it is important that all other grains should not be protected relatively more. Usually a much smaller protection of other grains will greatly strengthen the effect of protection given to wheat; for the competition of the other grains for land would be reduced by the resulting

increase in the price spreads between wheat and the other grains, while consumption of wheat would not be materially contracted even in most of those countries where non-wheat bread is still consumed in substantial amounts. With considerable success, wheat can even be the only protected grain, provided of course that production in the protected area does not outgrow consumption and thereby render the protection less effective or ineffective.

The position of rye as a food product is similar to that of wheat, but with some qualifications. Low protection of feed grains strengthens the competition of highly protected rye for the land without sensibly affecting its use for food. Rye production may also be favorably affected by low protection of wheat. Yet in the long run, competition of cheap wheat bread is likely to affect rye bread consumption more than cheap rye bread will affect consumption of wheat bread. Rye production in protected countries, moreover, much more easily exceeds domestic requirements, and then its reaction to protectionist measures is not different from that of feed grains.

High protection of a certain feed grain may easily fail to bring about a considerable increase in production in the protected area. Unless other feed grains are given a similar protection, the higher prices of the protected feed grains will inevitably result in a substantial shift of consumption to less protected feed grains. Isolated protection of a single feed grain may bring about enlarged production in the protected area only in those infrequent cases where the protection remains effective in spite of the expansion of the domestic production of the more protected feed grain and the shift of consumption to the less protected feed grains.

Surprisingly enough, the two extremes—larger or smaller relative protection of wheat—are regularly found, while equal relative protection is rather exceptional. Relatively lower tariffs on wheat were common in northern Europe. Sweden used to impose the same import duties per cental of wheat, rye, and barley, and that was equivalent to smaller protection of wheat.

For several years, Finland had the same duties on wheat, rye, and oats. Czechoslovakia for some time had duties on wheat even lower than those on either barley or oats. More important in this connection, Germany's duties on wheat for decades exceeded the duties on rye and oats by a lesser percentage than the prices of imported or domestic wheat exceeded similar prices of rye and oats.⁴ In Austria-Hungary, the ratio between the duties on wheat and rye was approximately the same as in Germany, while postwar Austria (until absorbed by Germany) imposed the same import duty on both grains. The tariffs on wheat, it is true, tended to be more effective than those of the other grains, especially those of feed grains. Yet in Germany the system of export certificates enabled rye and oats producers to enjoy almost the full advantages of tariff protection even when these grains were produced in excess of domestic requirements (see p. 173).

On the other hand, wheat has long had a disproportionately heavy protection in another significant group of countries. In France, the prewar import duty on wheat was more than twice as large as that imposed on the other grains, and in postwar years the difference was sometimes larger. The situation has been similar in Italy and, with some interruptions, in Spain. Switzerland joined this group in postwar years.

These differences in protectionist policies have been clearly reflected in the price ratios (Chart 3, p. 11). The spreads between the prices of wheat and those of rye and oats used to be almost as narrow in Germany as in neighboring countries without import duties, although Germany had a big deficit in wheat while rye and oats frequently showed burdensome surpluses. In Italy, on the other hand, the price ratios were not substantially different from those observed in remote exporting countries. The disparity in protection given to different grains in Italy fully compensated for the leveling effects

⁴ Since 1935 the duty has been 60 per cent higher on wheat than on rye, but this is immaterial. Even the duty on rye and the even lower duty on oats makes impossible any imports with payment of full duties. Foreign grain enters the country under some other, somewhat less prohibitive, regulations.

of both marketing costs and quality factors on the prices.⁵ In France and Spain, prices of wheat and the other grains were not so far apart as in Italy, yet the spreads were materially larger than in countries without import duties.⁶ The substantial widening of the spread between wheat and corn prices in Rumania in recent years (Chart 2, p. 10) also is caused by the extreme differentiation in price support. This is partly responsible also for the wide spread between wheat and corn prices in British South Africa (Chart 4, p. 12).⁷

In grain-protectionist countries in which rye bread is still important, rye has usually been protected relatively more than wheat. The great protection given to rye in Germany over long periods was heavily responsible for maintaining world production of this grain. In Denmark, Germany's neighbor, rye used to be slightly cheaper than oats and materially cheaper than barley (Chart 3). In Germany, however, rye has been persistently more expensive than oats, and, except in recent years, about as expensive as barley, if the average between the prices of feed and malting barley is taken for purposes of comparison. Rye was more expensive than oats in Austria and Sweden also. In Switzerland, which does not belong to the group of countries where rye bread is important, rye prices have even been kept *much* higher than oat prices.

Protection of food grains affects farmers as consumers only

⁵ The quality of the domestically produced grains in Italy is not nearly as effective in bringing the prices of wheat and of the other grains closer together as is true in northern Europe. Part of the Italian wheat is materially better in quality than wheat produced farther north, while the quality of Italian barley and oats is worse. But the quality factor may be a price-leveling factor if Italian prices are compared with prices in several exporting countries, as discussed in chapter v.

⁶ In Switzerland in recent years, the price spreads between wheat (and rye) on the one hand, and oats and barley on the other, have been wider than in almost any export region. Since the total amount of grain that can be produced in Switzerland is negligible, this fact has significance only as an illustration of the great power of modern protective weapons.

⁷ Owing to its natural conditions, the Union of South Africa for years exported much corn while importing wheat. Due to its isolated geographical location, such a situation resulted in a very wide price spread: the corn price was equal to world price *minus* large marketing costs while the wheat price was equal to world price *plus* substantial marketing costs. In recent years this spread has been further widened by the much stronger supporting measures in favor of wheat.

slightly because they use little if any food grain other than they themselves produce. If prices of feed grains are raised in the same manner, those feeders who buy grain—and most feeders are farmers—are also involved. If animal products are not sufficiently protected, their imports would rise, while the total demand may be substantially curtailed by the increase in prices made necessary by the higher feed prices. Consequently, many countries do not go so far—more frequently did not go so far in the past—as to impose high import duties on all feed grains.

So far as it was deemed desirable to leave one feed grain unprotected or only slightly protected, it has involved least friction in countries not producing corn or producing little of it to put corn in this privileged position. In postwar years, Finland had duties on all grains except corn, while Czechoslovakia imposed only a negligible duty on feed corn. In Sweden, corn has been left unprotected along with oats; in Austria, along with feed barley. This policy naturally was not followed in countries where corn production is important. Thus in Spain the postwar corn duty has been almost fully in line with the protection granted to other grains, and in Italy the duty on corn is twice as high as that on oats and feed barley.

Of the two feed grains of the cooler climates, oats and barley, oats frequently enjoy more protection than barley, because they are more important for domestic producers. Oats were the only grain which Belgium, even before the World War, decided to exempt from her traditional policy of free admission of grains. Attempts have sometimes been made to protect only malting barley, meeting the demands of feeders for cheap feed with milder treatment of feed barley, as in Germany, Austria, and Italy.

Effect on production, consumption, and trade.—Only a rough appraisal of the effects of protectionist policies on production, consumption, and trade in individual grains can be attempted here. Wheat production in protected countries un-

doubtedly was greatly enlarged by the protective policy. But total world production of wheat may have been adversely affected to some extent. For consumption of wheat in the protected countries may have been contracted by the resulting high domestic prices and, so far as rye is still an important bread grain, by the large support given to rye production. Hence international trade in wheat and the development of wheat production in surplus countries was probably held back even slightly more than the domestic production of wheat in the protected countries was stimulated.

World rye production has been kept up or increased by tariff protection of rye and wheat. In rye-eating countries which did not protect rye, or which gave it only little protection, per capita consumption of rye has declined more than in countries with heavy protection of rye. Once produced in greater quantities in some country, region, or locality, rye also is mostly consumed in greater quantities there. In the absence of protective policies, international trade in wheat would be enlarged, at least in proportion to the decline of production in deficit countries; but only a portion—and probably a rather small portion—of a similarly induced decline in the production of rye in unprotected countries would be reflected in the world rye trade. Moreover, while international trade in wheat on a much larger scale than at present might well continue under free-trade conditions, an enlarged world trade in rye would probably display at least as strong a tendency to dwindle as this trade has shown in the past.

Oats had the lion's share in the increase in production of feed grains in protected areas. For, as compared with feed barley, the greater protection on oats was in addition to the greater protection of marketing costs (see chapter vi). Even more important is the fact that oats are favored by natural conditions in the protected areas, whose suitability to oats production has in fact been the principal reason for the heavier protection. It is difficult to decide whether, under the influence of import duties, increase in the production of

oats and barley in deficit countries has exceeded the decrease in their production in exporting countries and in international trade in these grains; for a large portion of the additional production in surplus countries and of world trade in feed grains undoubtedly would have been captured by corn.

The foregoing statements as to the production of feed grains, and particularly as to the size of the international trade in these grains, in case of the absence of import duties, are made on the assumption that world consumption of animal products and the distribution of animal production among the individual countries would be the same as they are now. This assumption is hardly valid. Lower feed prices in importing countries would mean lower prices of animal products. This would bring about larger consumption of these products, provided the purchasing power of the population in importing countries were not lowered by removing the protection to domestic grain production. Furthermore, some deficit countries would probably find it advisable to import part of the additional animal products in ready-made form rather than the feed required in their production. Such shifts in animal production could hardly occur without some change in the amount of feed grain used per pound of meat or butterfat. Without discussing all these implications, it still seems fairly safe to conclude that, without protectionist measures or with only moderate ones, world production in feed grains would be larger and world trade much larger than now, with corn as the principal gainer.

HISTORICAL ASPECTS OF PRICE RATIOS

We have discussed the relative positions of the prices of individual grains at some length, beginning with the effect of consumers' preferences on the price ratios. Next the strength of these preferences has been tested by the analysis of the ease with which one grain is substituted for another under various supply and price conditions. Then followed a discussion of the effects on the price ratios of the variations in the quality of different grains as produced in different countries and of the cost of marketing the grain. Finally, we have considered import duties and other measures of government interference with the free flow of goods as they have affected the ratios between the prices of different grains.

In subsequent parts of this book attention will be directed toward the effect of production factors on the price ratios. Here brief mention of one factor important for analysis is appropriate. Time is not a primary factor. The price ratios have changed through time under the influence of changes in the factors investigated or those still to be discussed. Changes in the price ratios in the past, nevertheless, are a subject deserving separate consideration.

The major feature of long-time developments in the ratios between prices of different grains has been their tendency to approach each other as time passed. The price spread between wheat and the other grains remains relatively large, but wheat prices have shown a strong tendency to come nearer to the price level of other grains. For the price spread between rye and the feed grains, the tendency has been to disappear. As to malting barley—despite the lack of reliable price series—it seems safe to say that its prices tended to rise from a level more or less near the level of feed-grain prices to that of wheat, eventually exceeding this in some countries.

The relative depreciation of bread grains is equivalent to a

relative improvement of the prices of feed grains. The major specific developments with reference to feed grains have been two: corn prices have gained relatively most over the past 60-70 years; and oats prices have shown a decided tendency to lose relative to the prices of corn and feed barley in the past two decades.

The price situation in the beginning of the last century in northwestern Europe was as follows:

Period	Wheat	Rye	Barley	Oats
ENGLAND ¹ (<i>s.d. per quarter</i>)				
1801-10	83/9	....	37/6	28/1
1811-20	87/5	53/2	45/2	30/4
FRANCE ² (<i>francs per hectoliter</i>)				
1790-93	23.22	9.62	8.71	11.07
1802-10	19.50	10.89	9.46	9.13
1811-20	24.69	14.72	11.17	8.11

The official sources unfortunately do not present the data in comparable form. By using 492, 480, 448, and 336 pounds to the quarter, and 75, 70, 62, and 44 kilograms to the hectoliter of wheat, rye, barley, and oats, respectively, and taking wheat = 100, ratios appear as follows:³

Period	Wheat	Rye	Barley	Oats
ENGLAND				
1801-10	100	....	49.2	49.1
1811-20	100	62.3	56.7	50.8
FRANCE				
1790-93	100	44.4	45.4	81.3
1802-10	100	59.8	58.7	79.8
1811-20	100	63.9	54.7	56.1

Thus wheat prices at that time were much above the prices of all other grains, on the average almost twice as high.⁴

¹ Kurt Ritter, "Getreidepreise," *Handwörterbuch der Staatswissenschaften* (4th ed., Jena, 1927), IV, 899.

² *Bulletin de la statistique générale de la France*, October 1927-September 1928, XVII, 330.

³ The weights used must be fairly correct. For the quarter, the present legal weights have been used. In the French source, there is a remark that 3 hectoliters of oats were in 1847 considered equal to 140 kilograms, in 1848-51 to 145 kilograms. The weight of a hectoliter of wheat was 75 kilograms in 1821, for which prices were given both per hectoliter and per quintal.

⁴ Oats in France constituted an exception; but the French prices of coarse grains are for one market only and may not be representative.

English and French prices of rye may not have been quite typical for that grain. Farther east, rye prices in this period seem to have been sensibly higher relative to those of oats and barley than in England and France, where rye bread was rapidly losing all importance. In the Netherlands, for example, the average price of rye in 1801-20 was 8.55 florins per hectoliter, of barley 6.04, and of oats 3.76.⁵ On a pound basis, these prices indicate a premium for rye of nearly 30 per cent against barley and of nearly 40 per cent against oats.

It will be noticed that the prices of barley (covering both malting and feed barley) were only slightly higher than those of oats in England, and lower than oats prices in France. In other countries of western and central Europe also, the relative positions of prices of these grains were not uniform. In any case, malting barley at that time is likely to have been much less expensive than wheat, while feed barley alone probably was cheaper than oats. Corn was practically unknown in that part of the world.

The situation presented above pertains in general only to countries which either had deficits or were located close to deficit countries. In remote surplus regions, wheat not infrequently was three or more times as expensive as coarse grains. In Indiana, for example, wheat sold from 30 to 50 cents a bushel and corn at from 10 to 12 cents in the years 1830 to 1840.⁶ In northern Ukraine a similar relationship could still be observed in the 1840's and 1850's, shortly before the construction of railways. Wheat was the only grain which could stand the heavy cost of hauling to the Black Sea whence it could be shipped to importing countries. Even wheat could overcome the obstacle of being transported by wagon over hundreds of miles only because no feed was carried or bought on the way; the oxen used for this purpose were fed wholly on free pastures,⁷ and transportation occurred only in the

⁵ Kurt Ritter, *op. cit.*, p. 900.

⁶ J. B. Conner, *Indiana Agriculture* (Indianapolis, 1893), p. 5, quoted from P. W. Bidwell and J. I. Falconer, *History of Agriculture in the Northern United States, 1620-1860* (Washington, D.C., May 1925), p. 177.

⁷ The extreme south of Russia was then very sparsely inhabited.

spring and early summer. Moreover, the back load usually consisted of valuable salt from Crimea.⁸

By the end of the nineteenth century the situation had changed substantially. Thus in England prices and ratios were as follows:

Period	Wheat	Barley	Oats
PRICES (<i>s.d. per quarter</i>)			
1881-90	35/4	28/8	19/2
1891-1900	28/3	27/5½	25/7½
RATIOS			
1881-90	100	89.1	79.4
1891-1900	100	106.7	132.8

Wheat was unusually cheap, both absolutely and relatively, in the 1890's.^{8a} It is preferable, therefore, to use for the comparison with the earlier data the prices in the decade 1881-90, especially because the price relationships in Napoleonic times may have been particularly favorable for wheat. Even if allowance is made for this possibility, the data given above clearly indicate that the spread between the price of wheat on the one hand and of barley and oats on the other narrowed greatly in the course of the nineteenth century.

The ratios between British prices in Chart 3 show that in the present century the spread between the prices of wheat, oats, and barley widened slightly as compared with the 1890's. But if we again use for comparison the price of the decade 1881-90, the ratios of British prices as shown in Chart 3 testify to continuation of the development under way in the last century.

The reduction in the ratios between the prices of wheat and of barley and oats after the beginning of the nineteenth century was somewhat less on the "world" markets than on the domestic markets of the countries in northwestern Europe. The world wheat markets are now dominated by strong and medium-strong wheats such as were discriminated against before the development of modern milling technique. The aver-

⁸ Here the writer relies on his memory of a renowned investigation by the Russian Free Economic Society and Geographical Society.

^{8a} See H. C. Farnsworth, "Decline and Recovery of Wheat Prices in the 'Nineties," *Wheat Studies*, June and July 1934, X, 289-352.

age price of wheat imported into the United Kingdom in 1909-13 was 8.9 per cent higher than that of British wheat. Sixty years earlier the wheat that now commands the highest price in the world market would not have found buyers except for feed. But for farmers in regions where climatic conditions permit production of soft wheats only, it is a highly significant fact that oats and barley finally almost reached the price level of the only types of wheat which they can produce. Moreover, the narrowing of the price spreads between wheat and barley and oats was strongly marked even if in the comparison prices of soft wheat are used for the past while prices of medium or strong wheats are used for recent times.

Early in the nineteenth century, prices of rye in the Netherlands were much higher than those of barley and oats. In the closing decades of the same century they were barely equal to the prices of oats and exceeded the prices of barley by about 10 per cent. As shown by Chart 5 (p. 86) rye prices lost further ground in the last fifteen prewar years. The scarcity during the World War and the early postwar years again brought rye prices to a food basis, but later their drift toward the feed basis proceeded with renewed vigor. The exceptional rise of rye prices to approximately the wheat level, which occurred in 1936-37, does not represent a reversal of trend, particularly because it happened in the small world rye market which import barriers subdivided into a large number of almost independent units.

The price ratio between oats and all barley remained approximately unchanged during the nineteenth century, but malting barley probably improved its relative position. As indicated by the data in Chart 5, oats lost slightly to feed barley in the last fifteen prewar years. This may perhaps be explained both by an exceptionally favorable price situation for barley in the latest prewar years (large demand from Germany, where the duty on feed barley was much less than that on corn) and by the character of the price series⁹ of oats

⁹ The series is a combination of prices of the more expensive Russian oats and of the cheaper Argentine oats. Argentine oats probably affected it more at the end than at the beginning of the period.

used in Chart 5. On most important domestic markets, oats did not show signs of substantial weakening before the World War. In any case, the decline of oats prices, relative to those of feed barley and especially those of corn, is predominantly a postwar phenomenon. In the twelve postwar years for which prices of oats are given in Chart 5, Argentine oats averaged lower in price than Danubian or Russian barley in nine years while in one year the prices were equal.¹⁰ The same situation emerges particularly in North America (Chart 6). In none of the last fourteen prewar years were oats cheaper than corn in Chicago, but oats were the cheaper grain in ten of seventeen postwar years. Oats in Chicago averaged 7 per cent under corn in postwar years, while in fourteen prewar years they were more expensive by 22 per cent.

The price development of corn in northwestern Europe showed a considerable divergence from that of the other feed grains. Corn, which cost about 5 per cent less than oats in the English market in 1851-60, cheapened rapidly during the next few decades. In 1876-80 the price of corn was more than 30 per cent below that of domestic oats, and in 1891-95 the spread still amounted to almost 30 per cent.¹¹ In succeeding years and until the World War, corn regained part of the lost ground. In 1909-13, Argentine corn averaged approximately 15 per cent less than British oats in British markets.

In postwar years, corn again cheapened in relation to prices of imported barley (Chart 3). This price development cannot, however, be visualized properly without consideration of the fundamental change in the amounts of both grains entering international trade. Of total net exports of corn and barley, barley made up 44 per cent, on the average, in the five years ending with 1913-14 and only 17 per cent in the five years ending with 1936-37. In the face of such enlargement of the proportion of corn, the slight relative cheapening of the corn price is equivalent to a price improvement in favor of corn.

¹⁰ British import prices used for oats as "world market" prices in Chart 3 (p. 11) hardly present a correct picture. British imports of oats in 1932-36 consisted to a larger extent of higher-priced types and grades than did the prewar imports.

¹¹ *Encyclopædia of Soviet Exports* [translated title] (2d ed., Berlin, 1928), I, 190.

It is easy to demonstrate by data for individual countries that, with the same supplies, corn commands considerably better prices than before the war.

The proportion of imported corn to total supplies of barley, oats, and corn in the United Kingdom in 1903-04 to 1913-14 varied from 21.1 to 29.3 per cent. In 1924-25 to 1935-36 the variations were from 24.7 to 46.2 per cent (Chart 12, p. 113). Even in years with as low a proportion of corn supplies to total supplies of feed grains as 22.0 to 23.2, corn prices before the war did not exceed the average prices of all three grains by more than 8 per cent, while corn prices had to go down to a level 18 per cent less than the average of all feed grains to bring the proportion of supplies of corn to the total of the three feed grains to the moderate figure of 30 per cent. In more recent postwar years, corn prices on the English market remained at par with the other imported feed grains when the supplies of corn did not exceed this proportion.

The long-run changes in price ratios are caused partly by production conditions still to be discussed, but the major causes are found in factors which have been treated in preceding pages. The relative decline in rye prices was largely caused by the shift of consumption from rye to wheat bread. Steam transportation was the major reason for bringing wheat prices closer to those of other grains. One of the important reasons for the improvement of feed-grain prices relative to prices of food grains was undoubtedly the change in diet from one primarily vegetarian to one including large quantities of animal products. The depreciation of oats prices relative to those of other feed grains in the last two decades resulted from use of the internal combustion engine for transport on the road and for farm work. The improvement of world market prices of corn relative to the prices of feed barley over the last three-quarters of the century is the result of the gradual recognition by feeders in deficit countries and elsewhere of the high feeding value of this grain.

PART II

YIELD RELATIONSHIPS

CHAPTER IX

RELATIVE YIELDING CAPACITY

Differences between yields of the several grains from the same soil vary greatly in size. When expressed in units of equal weight, yields of certain grains may be greatly above the yields of some others. More frequently the differences are on the moderate side, and sometimes they are so slight that it is difficult to state which of the grains is the heavier yielder. Nevertheless, the relative yield per acre is undoubtedly the most important single factor in determining which grains shall occupy the land devoted to grain production. To a large extent, indeed, yield is the only factor that matters.

It was shown earlier (chapters ii-iv) that the content of nutrients, computed as the net energy value, does not differ much in different grains; that in the long run the interchangeability of different grains in the use as feed is considerable; and that from the feeders' point of view, their value as feed is thus largely about the same. In chapter xv an attempt will be made to show that the per-acre cost of production of the several grains—particularly the small grains—is frequently very similar, sometimes identical, and seldom widely different; largely differing per-acre costs, so far as they are present, mostly involve only one grain, corn. Thus we have approximately the same per-acre value of grains with respect to one of their two important uses, and also a rather similar per-acre cost of most of the grains. Hence, so far as the use of grains as feed is concerned, farmers tend to emphasize production of whatever grain yields the largest poundage per acre.

This phenomenon is faced most frequently in the case of oats and barley, although the best uses of these grains as feed diverge as much as those of any other two feed grains (oats are the best horse feed and barley is one of the best hog feeds—in Europe, the best). In many grain-producing areas,

oats and barley are grown either both as spring-sown or both as fall-sown grain, and are sown and harvested almost at the same time. The amounts of labor, power, and machinery necessary to produce them are the same or do not differ materially. Thus it is only natural that little or no barley is grown where oats outyield barley by as much as some 15 per cent, unless other outlets than for feed are available for the barley and the quality of the barley permits such uses. A difference in yield of 10 per cent may suffice for the same outcome. Relatively much oats are found in some regions where barley outyields oats, owing to the desire of farmers to feed their horses with oats or to the presence of local home-feeding demand. But for distant shipping, little or no oats are grown where the yield of barley is sensibly above that of oats.

The situation is slightly more complicated with reference to the competition between corn (and sorghum) on the one hand and oats and barley on the other. Corn usually requires more labor and power, though less machinery work, than oats and barley; but this merely means that corn has to yield enough more to repay the additional outlay. For corn (and sorghum) too, yield is the most important single factor determining the extent of its production.

Rotational requirements may limit the best-yielding grain to the position of the dominant rather than the exclusive grain crop. But here too the decision of the farmers is often in favor of the *highest-yielding combination* of grains.

Low relative yields do not debar wheat from a very important role in production. Yield is also not very significant for the place in production occupied by malting barley, another grain for which preference is pronounced. But broad masses of the population of a large part of the world still continue to use coarse grains as their staple food, and coarse grains are so used primarily owing not to preference, but because they are cheap; and they are cheap mostly because they yield better. Moreover, not only are large quantities of coarse grains rather than wheat grown and therefore used for food

owing to their higher yield, but yield is the principal factor determining the selection of specific coarse grains for production and consumption in specific areas.

For the predominant portion of world production of grains other than wheat and malting barley, yield is the principal or sole factor determining the choice of grains grown. This statement is not intended to cover rice, even though to some, probably very large, extent it is true also of this grain.¹ It is hardly an exaggeration to assert that yield is the principal or sole factor in the choice of grains grown for the larger part of world production of all grains.

The first section of this chapter presents a summary view of the relation between the grains with regard to yields, and mainly of differences in their inherent yielding capacity. The rest of the chapter is devoted to the discussion of the proportions of straw to grain in different cereal plants—a rather important but neglected factor bringing about differences between yields of different grains—and of the nature of available data on yields. Chapters x to xiii discuss the main factors responsible for the variations in the yield ratios in addition to inherent differences in the yielding capacity—soil, temperature, moisture, and cultural practices, respectively. Part II concludes with a short discussion of the changes in production techniques in the past as they have affected the differences in yields and the costs of production of different grains.

RANKING ACCORDING TO YIELDING CAPACITY

On the assumption that natural conditions are fair for each two grains compared, and that the comparison for small grains is either between fall-sown or between spring-sown grains, the five grains considered here rank approximately as follows with reference to yielding capacity (from highest to lowest):

¹ Rice is highly preferred by consumers but it is also a heavy yielder. Many densely populated regions have as an alternative to rice growing only noncereal carbohydrates which yield even more than rice. No grain other than rice could support those areas.

Corn	
Oats	Barley
Wheat	Rye

World averages are poor indicators of yielding capacity, owing to the wide differences in yields obtained under innumerable combinations of soil, climate, and intensity of cultivation. Yet it may not be mere chance that the ranking of the grains according to actual average yields coincides rather closely with the ranking presented above. In the five years ending in 1935, according to the *Yearbook of the International Institute of Agriculture*, world yields averaged as follows in centals per acre:

Corn	.....11.7
Oats	..... 9.7
Barley	..... 9.7
Rye	..... 9.4
Wheat	..... 8.3

That rye ranks materially above wheat in this tabulation is satisfactorily explained by the facts that, as compared with wheat, a much smaller proportion of the rye is produced in drier regions with their low yields and that rye is considerably more winter-hardy.

Arrangement of the different grains according to yielding capacity is justified by differences in such inherent properties of the grains as rooting capacity, ability to develop stiff stalks, and ratio of straw yield to yield of grain (pp. 203-10). But the conditions under which the grains are grown exert so strong an effect on their relative yielding capacity that a ranking based on their inherent properties must time and again be qualified or even reversed.

First of all, it is clear that grains can be ranked according to yielding capacity only in places where yields are possible. If a grain cannot be grown in some locality, there is no point in ranking it as to its yielding capacity at that place. This is particularly important for corn, which cannot mature in vast areas devoted to grain production. But the situation is differ-

ent only in degree with reference to wheat and barley, since soil conditions materially circumscribe the area where even moderate yields of these grains can be expected. Rye and especially oats have the fewest limitations.

If we should attempt to consider in our ranking yields so small as to be insignificant, the grain that would emerge as superior would be the one producing a crop under the greatest variety of natural conditions. Such a ranking would be of little use. It seems reasonable, therefore, to base our ranking on the assumption that natural conditions are fair for each two grains compared.

Another limitation of our ranking is perhaps that for small grains it can have substantial validity only so far as fall-sown grains are compared with one another, and spring-sown grains also with one another. The growing period of fall-sown grains is longer than that of spring-sown grains. They are mostly better supplied with moisture, and more often escape excessive heat. Hence the same grains usually yield better as winter than as spring grains. Such difference in yields, it is true, is not large where climatic conditions are equally favorable for both fall-sown and spring-sown grains; but even small additional yields of winter grains sometimes suffice to change the relative position in their favor. In the wide regions where weather conditions are more favorable to winter grains, the fact that some grains can survive the winter while some others cannot gives rise to substantial rearrangements in the regional rankings.

The assertion that corn exceeds all other grains in yielding capacity wherever climate permits it to be grown probably has relatively the greatest general validity. No other grain seems to yield as much as corn wherever climatic conditions are at least fair for the latter. Where climatic conditions are favorable to corn, its yield far exceeds those of the other grains, except perhaps on extremely acid soils. Moreover, corn frequently yields more than the other grains even though natural conditions are more unfavorable to corn than to the

others. Under conditions equally unfavorable for both corn and the other grains, corn again usually yields much more. Sorghum is not considered in the above statements. In the hot climate requisite for it, and with plentiful moisture, sorghum is not as inferior as the small grains in comparison to corn, and may even outyield it somewhat, while with insufficient moisture sorghum outyields corn materially; in very dry and hot air the superiority of sorghum is large, even under irrigation. Still, in the temperate zones of the occidental world taken as a whole, production of corn is probably held down at least as much by the impossibility of growing corn in vast areas which are either too cold for it, or have so little summer rain that no spring-sown grain can be successfully grown on it, as by weakness in competitive power under natural conditions where corn can be grown but yields too little to justify its production.

It is rather generally true that under conditions favorable for both barley and oats (neutral or slightly acid soils well supplied with nutrients in readily accessible form; sufficient but not excessive moisture; moderately warm temperature), the two grains will be approximately equal in yield with barley possibly having the edge. But there are wide territories where one of the two outyields the other more or less substantially. On soil of the type just described but receiving little precipitation, and especially on alkaline soils, barley is superior to oats. Oats lead on strongly acid soils with little nutrients in readily available form and/or where precipitation is ample, and mostly on soils less sour and with somewhat less ample precipitation but accompanied by considerable heat. The territories where barley is favored are wide; but the territories favoring oats, aside from being also rather extended, belong to those with generally high yields.

Since the difference between oats and barley yields is small where conditions are fair or better for both grains, the shift from spring grain to winter grain frequently enables the grain that can survive the winter to outyield the one more sensitive

to cold. Barley, the more winter-hardy of the two, has a certain advantage from the enlarged yielding capacity of winter grain, but this advantage is not of large significance, except locally.

Under natural conditions favorable both to wheat and rye (good soil, sufficient precipitation), wheat yields may exceed those of rye, especially under conditions of intensive or scientific agriculture. Natural conditions fair for both grains may still see wheat at the top, but the difference, if any, will be rather small. In conditions still more or less fair for rye but poor for wheat (light and/or rather acid soil), rye considerably outyields wheat, while wheat fails entirely on strongly acid or very light soil where rye still yields a meager return. On the other hand, where conditions are fair for wheat but less satisfactory for rye (good soil, hot dry climate), rye yields less than wheat or at least does not exceed it in yield.

Rye considerably exceeds wheat in winter-hardiness. Where wheat outyields rye, the difference in yield between winter and spring wheat frequently suffices to place winter rye above spring wheat in yielding power. The ranking thus becomes winter wheat, winter rye, spring wheat, spring rye. The large winter-hardiness is a very important asset of rye, especially since the difference in yielding power between winter and spring rye seems to be larger than for the other small grains.

Wheat in turn has an important advantage over barley and oats because of its greater winter-hardiness. In hot or drier and especially in hot *and* drier regions, winter wheat frequently tops both spring barley and spring oats. In moister areas, yields of winter wheat are close to those of spring barley and spring oats; and if they exceed the latter, the excess of yield in favor of winter wheat does not reach the considerable proportions observed in certain regions having hot climates and adapted to fall-sown wheat but too cold for fall-sown barley or oats.

Of considerable influence on the ratios between yields of different grains is the intensity of the methods of crop production. Under fair growing conditions wheat responds better

than rye to cultural practices—the strength of the response being measured in absolute quantities of grain harvested rather than in percentages. On the other hand, wheat is inferior to barley and sometimes to oats in response to some important cultural practices. But several factors combine to contract this difference in the response and even to make wheat superior. The inferiority in the response of wheat may be present and relatively strong where wheat competes with barley or oats, all of them being either spring-sown or fall-sown. But owing to the greater winter-hardiness of wheat, the competition to a large extent is between winter wheat on the one hand, and spring barley and spring oats on the other, in which case wheat may be superior in the response or its inferiority be less. Oats and (in less degree) barley are in danger of lodging if the soil is heavily fertilized. Such soil also is not conducive to production of the best samples of malting barley. Winter wheat indeed can stand the greatest amount of cultural practices. Moreover, the higher price of wheat frequently makes a lesser additional yield of wheat in response to cultural practices more profitable than a large additional yield of other grains, and it may therefore be advisable to produce wheat more intensively than any other grain studied here.² If produced under very intensive methods, winter wheat definitely outyields winter rye except on very light soils. Spring wheat comes much nearer to oats in these conditions, while the yield of winter wheat equals or exceeds the yield of spring oats.

Corn is the only grain which tends to respond to cultural practices—in terms of absolute quantities of grain harvested—much more strongly than winter wheat. But this much stronger response appears only in climatic conditions favorable for corn. Moreover, under almost any climatic conditions, the excess in yield of corn over winter wheat in terms

²The price of malting barley justifies as intensive methods as those used in wheat growing. But the weakness of the barley straw and danger of increasing the nitrogen content of the grain are limiting factors for the application of cultural practices to malting barley.

of percentages usually shrinks as intensity of crop production is increased.

The most important surpluses of wheat originate in regions where wheat has to compete with other grains as a spring-sown crop. The climate of the most important deficit regions, however, permits the growing of winter wheat while being too cold for winter oats and generally also for winter barley. Moreover, regions with large wheat surpluses practice extensive methods of crop production, while the most important deficit countries practice intensive methods from which the competitive power of wheat again gains. Thus we have a paradox: among the regions producing wheat, many of those producing the largest surpluses have the worst yields of wheat relative to the yields of the other small grains.

THE STRAW-GRAIN RATIO

So far as the value of the crop is concerned, the grain is the only or the most important portion of the grain plant. In fact, the term yield pertains to grain only, if not stated otherwise. But the land produces the whole plant rather than the grain alone. Yielding power obviously depends on the distribution of the total produce between grain and straw. Hence it seems advisable here to include a short discussion of the straw-grain ratio.³

The proportions of straw to grain are of particular import in drier climates, because usually all or nearly all available moisture is exhausted when the small grain crop has matured. There, moisture is the limiting factor also for corn, though corn is unable to exhaust all available water. More straw in the harvest means less grain. But the proportion of straw to

³Straw in the broad sense includes all residuals of the harvested plant after the grain has been threshed out or otherwise separated. The stover, which to represent all residuals should include the cobs of corn, is also straw in the broad sense. Where we have dealt with American data, the weight of the cobs has been added to the weight of the stover as given, assuming the former equivalent to 25 per cent of the weight of corn grain; a similar adjustment of Spanish data was made according to information from the Spanish Ministry of Agriculture; probably the same should have been done with the other foreign data. The straw-grain ratio is determined by dividing the yield of straw by the yield of grain (both expressed in the same weight unit) and multiplying the result by 100.

grain in the plant cannot be without influence on the yield of grain even where moisture is not the limiting factor. All necessary nutrients in a form accessible to the plants are not always abundant. Rooting power and power to grow are generally limited.

The *plants* of small grains differ in yielding capacity less than is indicated by comparisons of yields of grain alone. A large part of the difference is usually caused by the botanically rather irrelevant fact that wheat and rye are naked grains, while barley and oats do not separate from their hulls in the process of threshing. In wheat and rye the hull adds to the weight of the straw, while the hulls of barley and oats add to the weight of the grain. The soil tends to produce plants of more or less similar weight and composition. The direction that the hull goes in threshing causes more or less substantial variations in yield of grain and in the straw-grain ratio.

The stover-grain ratio of corn shows a definite tendency to be high if the yield of corn grain is small and vice versa,⁴ while no such tendency is observed with reference to small grains, and even the opposite may be true of them. It is of particular import that insufficiency of moisture tends to increase the straw-grain ratio of corn, while the application of nitrogenous fertilizer in the presence of sufficient moisture tends to lower it materially. In both cases the effect may be opposite on small grains.

Small grains usually rank as follows with reference to the straw-grain ratio, from smallest to largest: barley, oats, wheat, rye. Spring-sown small grains tend to have a lower straw-grain ratio than the same grains sown in the fall. Owing to the different behavior of small grains and corn with regard to the straw-grain ratio, at yields of different levels, in different climates, and with different cultural practices, corn cannot readily be included in the ranking.

⁴ Partly, probably, owing to variations in the number of cobs per plant.

The available data on straw-grain ratios are not fully in agreement;⁵ yet those given in Table 6 support the general conclusions just expressed. The only exception is that in Spain oats have a slightly lower straw-grain ratio than barley. But many other data indicate the position of barley as the small grain with the lowest straw-grain ratio.

TABLE 6.—STRAW-GRAIN RATIOS IN SPECIFIED COUNTRIES, AVERAGE 1931-35*
(Grain yield = 100)

Grain	England and Wales	France	Hungary	Spain
Rye .....	...	210	210	168
Wheat	126	160	190	140
Oats	117	149	172	115
Barley	95	128	162	117
Corn .....	...	...	187*	210

* Computed from official data in *International Yearbooks of Agriculture* by dividing the yield of straw by the yield of grain and multiplying the result by 100.

* Probably correction needed; see footnote on p. 203.

In the succeeding chapters, especially in chapter xii, we shall discuss the great superiority of barley over wheat in yield under conditions of limited supply of moisture in regions where these grains are both fall-sown or both spring-sown. Though no definite proof seems to be available, the idea is pressed on one's mind that the favorable straw-grain ratio of barley has much to do with that phenomenon. Experiments with the same grains, however, leave no doubt that under limited supply of moisture the alternatives frequently are grain *or* straw, the upper weight of the whole plant being determined by the available moisture. As an example, let us cite the time-of-seeding experiments with fall-sown wheat at Longernong Agricultural College, Victoria, Australia. Richardson reports:⁶ "Both with early and late sowing the amount

⁵ One of the reasons is differences in thoroughness of saving the straw which impairs comparability of the data on straw-grain ratios, at both different and the same places.

⁶ A. E. V. Richardson, *Wheat and Its Cultivation* (Victoria, Australia, Dept. Agr. Bull. 55, New Series, 1925), p. 187.

of *total* crop produced was much the same, the tendency being towards the production of larger total crops from the early sowings." But the yield of grain from late sowing exceeded that from early sowing by 15.2 per cent on a seven-year average.⁷

The fact that barley and oats are harvested encased in the hull while wheat and rye are obtained with the hulls removed considerably affects the ranking according to straw-grain ratios. The ranking sometimes would even be reversed, if a large part of the hull of the hulled grains were transferred to the straw.⁸ In Germany, for example, the straw-grain ratio would be in this case more favorable for spring wheat than for oats; in Bessarabia even winter rye would be ahead of oats.⁹ The principal differences in straw-grain ratios of small grains which remain after the effect of hulls has been eliminated are that rye and oats tend to have less favorable ratios than wheat and barley, respectively. Barley is superior to all small grains in the straw-grain ratio, on the basis of either *grains as threshed* or *hull-less grain*.

The presence of hulls in oat grain and barley grain, and the differences in the proportions of hulls to total grain in them, affect not only yields but also usefulness (chapter ii). Some students therefore feel justified in making comparisons of yields of different grains on the basis of *hull-less grain*. While there is justification for this in the greater similarity of the content of nutrients, the procedure is inappropriate for general use, for all statistics are on the basis of *grains as threshed*. But it is well to bear constantly in mind that the

⁷ The same observation was made in Nebraska. See T. A. Kiesselbach and others, *Cultural Practices in Winter Wheat Production* (Nebraska Agr. Exp. Sta. Bull. 286, April 1934), p. 14.

⁸ It would be incorrect to count the weight of the whole hull of oats and barley with the straw, since the skin of the naked grains is thicker than the corresponding portion of the hulled grains.

⁹ The statement for Germany is based on average yields of straw and grain for the whole country in two years. It may not be true for the same localities or for averages of more years. The statement on Bessarabia is based on five-year averages of the official prewar statistics.

major difference between small grains in yield, and frequently all of it, is due to the different destination of hulls.

Corn has a high straw-grain ratio in Spain and probably in Hungary (Table 6). The main reason is the rather low yield of corn grain, but the scarcity of feed in such densely populated countries may also be a factor. Data from experimental fields in the United States (no official statistics on straw and stover yields are available) likewise show that in regions where yields of corn are low, corn usually does not occupy a favorable position with reference to the proportion of stover to grain; but the data also indicate a strong tendency of the stover-grain ratio to improve (i.e., to decline) as the yield of corn grain rises. Particularly important is the tendency of corn to produce relatively much stover in drier climates, especially where scarcity of moisture is accompanied by high temperatures, exactly where water is the limiting factor. At the experiment station of Manhattan, Kansas, the yield of stover is more than twice the yield of corn grain.¹⁰ In regions still drier than Manhattan, the stover-grain ratio may be as high as 400 or more.¹¹

In the Corn Belt the situation is much more favorable for corn. At State College, Pennsylvania, corn had a lower straw-grain ratio than either winter wheat or oats, while at Lafayette, Indiana, the stover-grain ratio of corn occupied an intermediate position (Table 7). The peculiar behavior of the stover-grain ratio of corn under different climatic conditions is apparently the reason that, in terms of grain, corn proves so very efficient in using additional moisture (pp. 291, 305-06).

Factors other than moisture, such as the length of the growing period and especially the value of the stover, are also important for the differences in the straw-grain ratios between

¹⁰ R. I. Throckmorton and F. L. Duley, *Twenty Years of Soil Fertility Investigations* (Kansas Agr. Exp. Sta. Tech. Bull. 40, October 1935).

¹¹ At the Northern Montana Branch Station the ratio for continuous corn which on an 18-year average yielded 12.4 bushels of corn grain, was 505 on fall-plowed land. M. A. Bell, *The Effect of Tillage Method, Crop Sequence, and Date of Seeding upon the Yield and Quality of Cereals and Other Crops Grown under Dry-Land Conditions in North-Central Montana* (Montana Agr. Exp. Sta. Bull. 336, February 1937), p. 21.

TABLE 7.—YIELDS AND STRAW-GRAIN RATIOS OF SPECIFIED GRAINS AT SPECIFIED EXPERIMENT FIELDS*

Treatment	Wheat			Oats			Corn		
	Yield (lbs. per acre)		Straw-grain ratio ^a	Yield (lbs. per acre)		Straw-grain ratio ^a	Yield (lbs. per acre)		Stover-grain ratio ^a
	Grain	Straw		Grain	Straw		Grain	Straw	
STATE COLLEGE, PENNSYLVANIA (AVERAGES OF 1882-1921)									
Unmanured	768	1,178	153	1,002	1,239	124	1,999	2,293	115
Manured ^b	1,428	2,304	161	1,398	2,121	152	3,500	3,587	102
Percentage gain	86	96	...	40	71	...	75	56	...
WOOSTER, OHIO (AVERAGES OF 1894-1923)									
Unfertilized	597	1,008	169	935	1,191	127	1,331	1,748	131
Fertilized	1,202	2,225	172	1,441	1,918	133	2,215	2,480	112
Percentage gain	116	121	...	54	61	...	67	42	...
PURDUE FARM, LAFAYETTE, INDIANA (AVERAGES OF 1890-1917)									
Unmanured	738	1,160	157	1,110	1,117	101	1,574	2,148	136
Manured ^b	1,104	1,872	170	1,466	1,554	106	2,274	3,024	133
Percentage gain	50	61	...	32	39	...	44	41	...

* Data from C. F. Noll and others, *Fiftieth Anniversary of the General Fertility Tests, 1881-1931* (Pennsylvania Agr. Exp. Sta. Bull. 264, May 1931), p. 7; C. E. Thorne, *The Maintenance of Soil Fertility* (Ohio Agr. Exp. Sta. Bull. 381, June 1924); and A. T. Wiencko, S. C. Jones, *The Value of Manure on Indiana Soils* (Indiana Agr. Exp. Sta. Bull. 222, September 1918), p. 11.

^a Grain yield = 100. See also footnote 3, p. 203.

^b Six tons manure applied to corn and wheat.

^c Data for light applications. Manuring in proportion to total crop: since 1903, 3 tons to corn and 2 tons to wheat and oats. With 4 tons manure (heavy applications) since 1903, oats and wheat over the whole period averaged 1,491 and 1,302 pounds of grain, respectively.

corn and small grains. Data from accounting farms in New York,¹² for example, show a straw-grain ratio for corn higher than for any other grain, in spite of a moderately high level of yields; the high value of straw in that state is the explanation. On the other hand, the Russian official prewar data indicated favorable stover-grain ratios, although yields of corn grain were low.

Almost as important as is the tendency of corn to show lower stover-grain ratios in regions with high yields of corn grain, and vice versa, while the ratios of small grains tend to remain stable or even to alter in the opposite direction, may be the fact that similar tendencies can be observed at the same places. With rare exceptions, every increase in the yield of the whole corn plant improves the stover-grain ratio. The additional weight of the corn plant goes in enlarged proportion into grain. The data in Table 7 show this clearly for increases in yield attained by manure and fertilizer. The same seems to be true for increases resulting from other cultural practices. In four years' experiments at the Virginia Agricultural Experiment Station, the stover-grain ratio of corn exceeded 300 on plots on which corn was not cultivated and the yield of corn grain averaged 8.17 bushels, whereas the ratio was slightly over 100 on plots receiving three and five cultivations and yielding 59.43 and 58.68 bushels of corn grain, respectively.¹³

Small grains, on the other hand, show higher straw-grain ratios on manured and fertilized plots than on unmanured and unfertilized plots in all illustrations given in Table 7. Such results do not always occur if the grain yield of small grains is increased by fertilizer or cultural practices, but they seem rather general at least with reference to such important cases

¹² G. F. Warren and others, *Cost Accounts for Six Years on Some Successful New York Farms* (Cornell Agr. Exp. Sta. Bull. 414, February 1923), and J. F. Harriott and L. M. Vaughan, *Cost Accounts on New York Farms* (Cornell Agr. Exp. Sta. Bull. 554, April 1933).

¹³ T. B. Hutchesson and others, *Corn Culture* (Virginia Agr. Exp. Sta. Bull. 214, March 1917), p. 8.

as application of commercial fertilizer containing a large proportion of nitrogen, or manure, and the inclusion of leguminous hay in the rotation. A tendency for consistent substantial declines of the straw-grain ratios of small grains seems not to be present under any circumstances. This difference in the behavior of the straw-grain ratio between small grains and corn at different levels of yield must be largely responsible for the superiority of corn in the response to cultural practices where climatic conditions are favorable to it.

METHODOLOGICAL CONSIDERATIONS

In view of the great significance of the grains and their yields in the economy of the world, one is somewhat surprised to find that it is rather difficult to get an exact idea about the ratios between yields of different grains under various conditions.

To begin with, statistical data can be used for this purpose to only a moderate degree. Average yields of different grains as obtained in a certain area are seldom comparable. The most important disturbing fact is that the soil on which different grains are grown varies materially. Rye in general, and oats to a large extent, are grown on poorer soil than wheat, barley, and corn. In New York state, for example, barley out-yielded oats by 30 per cent on the average in 1923-32; yet there is little doubt that on good soil on which barley is grown (farmers would not attempt to grow barley on poor soil) the superiority of barley over oats in yields, if any, is less than this. The difference in the soil used for different grains is so important that it can destroy the comparability of data from areas even as small as a county. Moreover, differences in the type of soil for different grains are common even within a farm. The best fields and the best places in rotations are picked for the crop that gives the best financial return. In drier regions usually, in many other regions frequently, wheat will get the chosen place. In regions with a corn climate, however, corn may be in this position. Rye rarely enjoys such

privileged treatment, except where poor soils are fallowed. Oats too, except under specific conditions such as prevail, for example, in the Corn Belt, tend to be grown on poorer soils and in poorer places in rotations.

In the Prairie Provinces of Canada a large proportion of the wheat is grown on fallowed land while other grains are practically always grown on stubble. Fallowing there increases wheat yields by 40 per cent, according to our somewhat arbitrary calculations (p. 391). The growing of wheat on fallow and of the other grains on stubble land occurs also in North Dakota, South Dakota, southern Russia, Australia, and some other countries. In northern and central Russia and adjacent countries where the soil is inappropriate to wheat, much rye is grown on fallowed land because of the managerial advantages of using the fallowed land for a winter crop. Yields of such rye are not comparable with those of oats, which are usually grown on the rye stubble.

There are better and worse places in the rotation even where the land is not fallowed. In the Great Plains, for example, all small grains of spring habit yield better on corn stubble than after the same or another small grain (pp. 316-17). The advantage of having small grains follow potatoes or roots in the rotation is even greater than to have them follow corn. The place in the rotation after clover or alfalfa is an extremely favorable one in the moister areas. Where corn is grown, this grain usually gets it. In regions unsuitable for corn, wheat may have the choice. Oats, and in some regions rye, are regularly grown in the worst places of the rotations.

But yields per acre of different grains may not be comparable even if difference in the place in the rotation is not a factor. Owing to specific requirements of different grains and to differences in prices, variations occur in the application of fertilizer, the thoroughness of preparation of the soil, and other operations as well. The most important fact of this kind in the United States is that most of the manure is applied to corn. So far as the use of commercial fertilizer is profitable, malting

barley shares with wheat the position of the crop to which application in large quantity is more profitable than to other grains.

Last but not least, such an inconspicuous form of preference as the order of seeding may be mentioned. Spring wheat, spring oats, and spring barley grown in drier climates frequently profit materially from being seeded at the earliest date possible, and this date is either the same for all of them or does not vary much. A delay of a few days from the optimum date causes some reduction of average yields of all these grains, and a delay of a few weeks may reduce them greatly. Experiments at North Platte, Nebraska, based on a 14-year period, showed the following relations between time of seeding and yield of three spring grains in bushels of legal weight:¹⁴

Grain	Average seedtime			
	March 25	April 6	April 18	April 30
Spring wheat	12.0	10.9	7.6	6.0
Spring oats	27.6	27.8	24.3	20.9
Spring barley	23.4	21.7	19.3	14.5

The quality of all small grains also is affected adversely by delay.¹⁵ Since spring wheat suffers most from the delay, and since it also is the most valuable crop, it is usually sown first. Delay in seeding the other grains may be small when all are sown on land prepared in the fall, but this is not always done even where fall preparation is more favorable for yields than spring preparation.¹⁶

The picture of relative yielding power given by statistics

¹⁴ Data from L. L. Zook and W. W. Burr, *Sixteen Years' Grain Production at the North Platte Substation* (Nebraska Agr. Exp. Sta. Bull. 193, July 1923), pp. 32, 37, 42.

¹⁵ The test weight of spring wheat on the average in 1917-23 fell from 55.6 pounds per bushel for early seeding (March 31) to 53.8 (seeded April 12) and to 51.7 pounds for the late seeding (April 20) at the Nebraska Experiment Station. The corresponding figures for oats were 29.1, 27.8, and 27.4 pounds per bushel. T. A. Kiesselbach, "The Relation of Seeding Practices to Crop Quality," *Journal of the American Society of Agronomy*, August 1926, XVIII, 672. Similar data could be presented for barley.

¹⁶ In the Great Plains, spring-plowed land usually outyields fall-plowed land.

of average yields is likely to be definitely disturbed whenever several of the enumerated factors operate simultaneously, and particularly when the data apply to countries with large divergences in soil and climatic conditions. Average yields of different grains in Germany ranked as follows relative to winter wheat, in the period 1931-36:

Winter barley	113.8
Winter wheat	100.0
Spring wheat	95.4
Spring oats	90.3
Spring barley	89.4
Winter rye	79.4
Spring rye	60.4

There is relatively little in this ranking that may be regarded as in agreement with inherent properties of the different grains. It is unlikely that, under German climatic conditions, winter wheat even on the best wheat soils outyields winter rye by more than 25.5 per cent or that winter rye outyields spring rye by 31.5 per cent. The fact that winter wheat outyielded oats by 10.7 per cent is likely to have been caused—wholly or to a large extent—by the growing of wheat under less climatic vista, on better soils, and in better places in the rotations, and by providing it with more plant food of every kind.

The order of attention (including the care, the selection of soil and climate, the place in rotation, and the amount of fertilizer and cultivation) given to different grains in Germany is approximately as follows, from the largest to the least: winter barley, spring wheat, winter wheat, spring barley, oats, winter rye, spring rye. This order seems to be reflected in the yields obtained as strongly as the inherent properties of the different grains.

The use of data on average yields for smaller subdivisions than a whole country mostly eliminates part of disturbing factors, but the possibility of spurious results and statistical errors grows as the size of the area diminishes. The danger is greatest with statistics on yields of crops with only small acreages.

In view of the important reasons for distrusting average yields obtained in whole sections, one hopefully turns to the data of the experiment stations, only to find that definite conclusions are equally dangerous. Many experiment stations do not arrange their plots in a way that permits comparisons to be made of the yielding capacity of the different grains. In the Corn Belt, for example, it is taken for granted from the outset that oats cannot repay application of manure as efficiently as some other crops. With only minor exceptions, manure is applied either solely to corn or to corn and wheat. The famous experiments at Rothamsted permit comparisons only between the yielding capacity of winter wheat and spring barley.

Furthermore, the significance of all experiments is materially limited by the great difficulty of finding fields in which every plot is of exactly the same productivity. There may be further differences in the amount of damage caused by rain or hail. Hence rather divergent results are frequently obtained when the same treatment is used on several plots. So far as several plots with the same treatment are available, averages can be computed. But some experiments are conducted on single plots only. Last but not least, the risk involved in generalization of results obtained on tiny plots (some are as small as $\frac{1}{20}$ of an acre and less) to millions of acres grown on farms must be considered. Elaboration of the great uncertainties surrounding the results of field trials occupies a very pertinent part of the vast literature devoted to these trials.¹⁷

¹⁷ See, for example, F. L. Engledow and G. U. Yule, *The Principles and Practice of Yield Trials* (London, 1926), and Theodor Roemer, *Der Feldversuch* (Arbeiten der deutschen Landwirtschafts-Gesellschaft, Heft 302, Berlin, 1930). An almost endless literature is quoted in the latter study.

CHAPTER X

SOIL

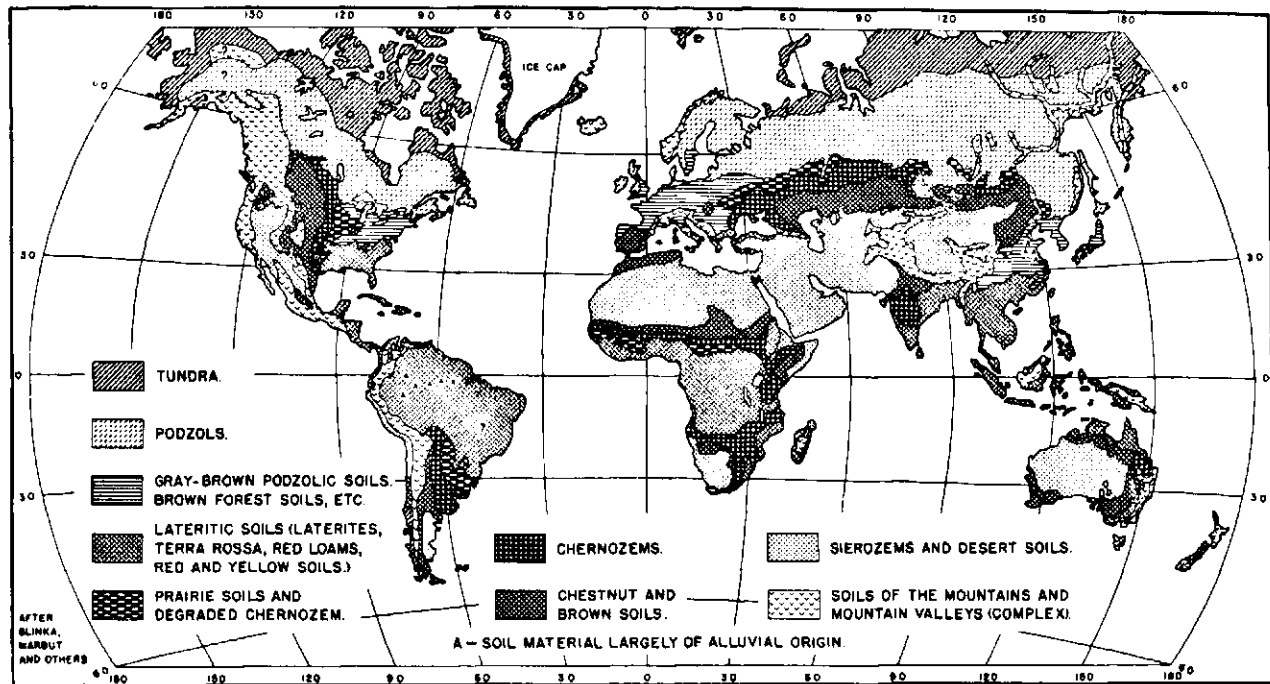
THE SOILS

The great achievements of man in overcoming obstacles imposed by nature are well known. These achievements are large in agriculture; much more food and feed can now be obtained than was possible for our forefathers with the same expenditure. The changes that have been made have materially affected the place of grains among other crops and the competition among the grains themselves. Yet in spite of immense progress, crop production remains under great limitations imposed by nature. This is true with regard to both climate and soil, and the properties of the crops. Although much has been achieved in adjusting the properties of the different soils to the various requirements of different crops, and the properties of the crops to the different soils, the differences between the original properties of the soils preserve much of their significance.

The two most important broad types of soils are those whose native vegetation is (*a*) grass or (*b*) forest. Grassland soils in general develop in regions where precipitation does not suffice to leach them; their subsoils are always dry. So long as they remain grassland, these soils usually have an alkaline reaction and their content of minerals and humus (organic matter) increases. Grassland soils are subdivided into prairie, black (*chernozem*), chestnut, and brown soils. The color of the last three types is broadly indicative of quality, for it reflects the amount of humus accumulated in the soil, humus being one of its most valuable ingredients.¹ Prairie soils, which develop in regions with climates similar to

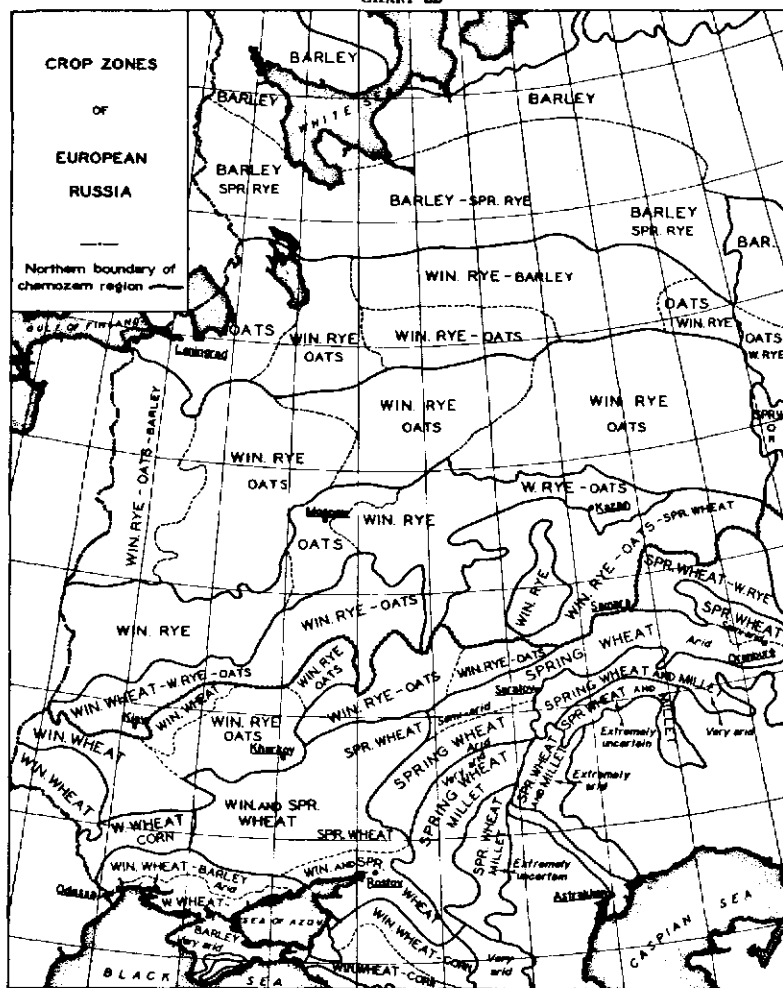
¹ Humus is the source of nitrogen needed by the plants. Consisting mostly of colloidal substances, it also greatly increases the water-holding capacity of the soil. Humus makes light soils heavier and heavy soils lighter. The power of grassland soils to retain their productivity over a long period depends greatly on their humus content.

CHART 21.—SCHEMATIC PRESENTATION OF IMPORTANT SOIL GROUPS*



* Courtesy of U.S. Department of Agriculture, Soil Survey Division. Thanks are due to Dr. Charles E. Kellogg, Chief of the Division, for providing the chart and making suggestions for this section.

CHART 22*



* Adapted from a similar map in *Rasteniewodstwo SSSR* [The Crops of USSR] (All-Russian Crop Institute of the People's Commissariat of Agriculture of the USSR, Leningrad and Moscow, 1933). "The map is prepared under consideration of the shifts in acreage of the individual crops, as regarded desirable in the interests of the national economy and the reconstruction of agriculture, as well as in agreement with the requirements of the crops as to soil and climate . . ." (p. 87). Only the zoning of grains was adapted from the original map, which covers other crops as well. Slight changes have been made in the map in agreement with other maps and information contained in the study. European Russia is customarily divided into the chernozem (black soil) and non-chernozem zones. The black-soil zone located south of the heavy line includes also prairie soils (designated in Russia as heavy chernozem), degraded black soils, chestnut soils, and other steppe soils.

those of the preceding group but are relatively well supplied with moisture and may therefore be slightly leached and moderately acid, are comparable in productivity to black soil.²

One of the two largest blocks of such soils includes portions of Hungary and Rumania, small portions of Poland, patches of Germany, and most of southern and southeastern European Russia, extending far into Asiatic Russia. (In Chart 22 the chernozem or black-soil zone of European Russia is separated by a heavy line from the zone of forest soils designated in Russia as the non-chernozem zone.) The second large block of this type of soil extends in a wide belt from north to south in North America, as shown in Chart 21. The two large blocks are approximately of equal size. The Argentine pampas constitutes the largest of the smaller stretches of such soils.

Forest lands possess opposite characteristics. Precipitation usually exceeds evaporation. The soils are therefore moist in their lower strata and permanently leached, their usual reaction is from moderately to strongly acid, and the humus content is small. On wide stretches of such land, especially in the tropics and in the north, leaching has advanced so far that little lime and soluble plant nutrients are left. Dependent on parent material, forest soils show variations from clay to extreme sandy soils, and owing to the small humus content the most undesirable types tend to make up a large proportion of the total.

Aside from the large stretch of grassland soil in eastern Europe and portions of the Iberian and Balkan peninsulas, all European soils comprise formerly forested land. In America, all of the soils east of the Mississippi and a considerable proportion of the soils in the northwest were, or still are, forest land.³ Gray forest soils of cool, moist climates, designated

²The Russian "chernozem zone" is equivalent to the zone of grassland soils. In Canada, "prairie" designates grassland of any type.

³See the chart showing natural vegetation in O. E. Baker, *A Graphic Summary of Physical Features and Land Utilization in the United States* (U.S. Dept. Agr., Misc. Pub. 260, May 1937), p. 11.

in Chart 21 *podsoles*, which extend all through northeastern Europe, Asia, and North America up to the *tundra* in the north, are the poorest species of forest soils in temperate zones. Brown podsol forest soils or, as they are usually referred to, brown forest soils of the type met with in west central Europe and east central United States, formerly in deciduous hardwood forests, are considerably superior in fertility. They are little leached, and therefore usually contain larger amounts of accessible plant food and humus than other types of forest lands.

Two aspects should be distinguished with regard to the effect of the properties of the soils—whether original or brought about by human effort—on the competition of and among the grains. Their immediate effect is on relative yields and production costs as currently obtained and incurred. An idea of this effect can be formed from the differences in the soil requirements of the grains discussed in the last section of this chapter and from the response to cultural practices treated in chapter xiii. The other aspect is that of the differences in the potential long-time fertility brought about by the original properties of the soils and by the ways in which man uses them. The grains cannot fail to be affected by what will happen in the future to the soils on which they are now grown. The brief discussion of long-time fertility in the next section includes also an appraisal of the changes in the original properties of the soils by their cultivation.

LONG-TIME FERTILITY

Some widely distributed soils are known to have been cropped for 2,000 years and more without returning anything to them, and yet without marked change in their fertility. Of the fertility of the chernozem soils, Marbut writes that the thickness of the layer containing a high percentage of the constituents of fertility "is so great that the world's experience up to the present time affords no basis for placing any estimate

on the duration of the productivity of these lands."⁴ The whole topsoil of some soils was blown away, and the subsoil continued to produce as the topsoil had done before. Other soils, however, also found in large stretches, contain a reserve of fertility sufficient for only a few decades and sometimes for not so long. Moreover, some soils which in general are well supplied with plant food contain little of certain indispensable kinds.

A rational handling of the natural resources contained in the soils should be quite diversified under these conditions. Where nutrients are present in large quantities, their exploitation is perfectly justified. Operations intended to make such supplies accessible to the crops may well be regarded as accomplishing all that is desired, whereas soils with small supplies of plant food should be used on the basis of full restoration of the outgo. Although farmers by and large follow this policy, exceptions are frequent and of vast import. No practices other than those intended to help the plants to extract the nutrients more efficiently are used by a very large proportion of farmers on both rich and poor soils. All that they do is to loosen the soil and perhaps also to keep down weeds. Rotations also are used almost universally, it is true, but many do not include crops that increase the organic matter and/or nitrogen in the soil. Such rotations, if not accompanied by application of manure and/or fertilizer, are primarily an efficient extracting practice, which entails ultimate exhaustion sooner than the growing of one crop only on the same land.

Not all farmers, of course, limit their operations to purely exploitative practices. A material part of the nutrients taken from the soil is returned as manure, which is also rich in organic matter. Widespread also is the inclusion of grass in the rotations, and grass, though it removes miner-

⁴C. F. Marbut, "Russia and the United States in the World's Wheat Market," *Geographical Review*, January 1931, XXI, 5. See also O. E. Baker, "Agricultural Regions of North America: Part VI—The Spring Wheat Region," *Economic Geography*, October 1928, IV, 425-26.

als, enriches the soil with organic matter—in the case of leguminous sod with nitrogen also.⁵ Last but not least, commercial fertilizer should be mentioned.⁶ But the proportion of grass in rotations is seldom considerable except in some regions with very large precipitation, and the supply of nutrients returned to the soil in the form of commercial fertilizer is also relatively moderate.⁷ Definite improvement in soil fertility seems to occur only with reference to the proportion of strongly acid soil, which is slowly but persistently declining, and with regard to bacterial life stimulated by the continuous working of the soil. With regard to nutrients and organic matter, the outgo—which is not restricted to quantities actually used by the plants but includes also huge amounts lost through erosion⁸ and leaching—is presumably not offset by gains. Crop production in the world as a whole may be considered still in the extractive phase.

Widely differing regional trends can be observed with regard to changes in soil fertility. By plowing, which exposes the mineral substances of the soil to the air and to the attack by bacteria, applying enormous amounts of manure and mod-

⁵ Nitrogen fixed by legumes may amount to as much as 80 pounds and more per acre per year.

⁶ Aside from the plant food and organic matter added by cultural practices, the soil is enriched by the nitrogen coming down with the rain and that which is fixed by nonsymbiotic organisms. According to Oswald Schreiner and B. E. Brown, "Soil Nitrogen," *Soils & Men, Yearbook of Agriculture, 1938*, p. 364, the first source yields 5-7 pounds and the second about 25 pounds per acre per year.

⁷ In 1936, according to the *International Yearbook of Agricultural Statistics, 1937-38*, 2.66 million metric tons of potash fertilizers (in terms of pure potash) were produced in the world. The amount of phosphates (in P_2O_5) and nitrogen used in world agriculture in the same year was equivalent to slightly less than 5 million and more than 2 million metric tons, respectively. The total of all three nutrients is approximately 10 million metric tons. If we assume that, allowing on the one hand for unavoidable losses through leaching, and on the other hand for the nitrogen coming down with the rain and fixed by nonsymbiotic organisms, 50-60 kilograms of plant food (nitrogen, phosphoric acid, and potassium) are needed in the production of grain and straw per metric ton of grain, world production of commercial fertilizer would suffice for the production of 160-200 million metric tons of grain. This quantity is equivalent to about 25-30 per cent of the world production of grain. But the predominant portion of fertilizer is probably used for crops other than the grains here studied, such as cotton, beets, vegetables, and potatoes.

⁸ Of course, part of the fertility removed by erosion in one place enlarges fertility somewhere else. Part, however, is carried into the ocean or otherwise definitely lost.

erate to large amounts of commercial fertilizer, using lime, growing leguminous crops, draining, irrigating, and the like, a large part of the soils in northwestern and north central Europe and smaller areas elsewhere are continually being improved. Organic matter increases; soil acidity diminishes; and the content of nutrients becomes more appropriate to the needs of the crops, for nutrients originally present in small quantities are augmented while reductions are confined mainly to nutrients present in large quantities. At the other extreme, both in regions with abundant precipitation such as the southeast of this country and in very dry regions such as western Kansas, cultivation as now conducted not only leads to exhaustion of important nutrients within a few generations, but part of the land becomes worthless through the removal of the whole topsoil by rain, wind, and gullyng.

All sorts of intermediate trends could be pointed out. It has been claimed by some, for example, that careful balancing of input and removal has left soil fertility unimpaired in much of China for several thousand years. Still, the proportion of soils from which the supplies of nutrients are mined more or less rapidly is very large, at least if the comparison is made on the basis of acreage rather than of output.⁹

There are several reasons for the wide divergences in methods of handling the natural resources contained in the soil. A rather fortunate one, from the point of view of long-time fertility, is that some of the widely cultivated soils would be practically unusable unless provided with nutrients and organic matter, or drained, irrigated, or otherwise improved. Another pertinent reason, but a rather unfortunate one from the same point of view, is that it is not economical for farmers to use long-time fertility as the principal guide in their activities. Except possibly in such countries as China, long-

⁹ Ohio is not among the states usually mentioned when alarms are sounded on losses in long-time fertility, yet G. W. Miller writes in "Soil Productivity Related to Farm Organization and Income," *Journal of Farm Economics*, February 1939, XXI, 108: "There is evidence in Ohio that the productivity level of the soils of the State as a whole is not being maintained."

time fertility is not kept up unless the outlay can be repaid by current increase of returns. Actually even such outlays are neglected in many countries and by millions of farmers. Long-time fertility at best is an unpaid-for accessory of immediate increase in yields.

The ability of plants to repay enlarged amounts of nutrients or organic matter, however, is conditioned upon the presence of a sufficient amount of moisture. The larger the water deficiency, the less in general is the response of plants to applications of fertilizer in any form, except to relieve great scarcity of specific nutrients. In very dry conditions the response is frequently even negative. Moreover, maintaining the fertility of very dry arable land is as yet an unsolved technical problem, even without regard to cost.

The problem of long-time fertility is given much attention even in countries in which soil fertility is apparently on the increase.¹⁰ Even more concern can naturally be observed in countries where crop production still remains mainly or exclusively an extractive industry.¹¹ The recent droughts accompanied by a conspicuous degree of erosion made long-time fertility a major public issue in the United States. The problem is carefully studied even in such agriculturally new countries as Canada and Australia, and warnings are sounded almost uninterruptedly. Perkins, for example, presented a paper on this subject to the Agricultural Bureau of Australia as long ago as 1916, but his recommendations seem to have exerted little or no influence on policy or practice.¹²

The competition of and among the grains for the land is affected by the different trends in long-time fertility because the crops are grown in widely divergent proportions on soils

¹⁰ See, for example, the publications by E. J. Russell, extensively drawn upon for this study, or the comprehensive study by R. W. Böhme, "Die Dauer der Ertragsfähigkeit der Böden unter verschiedenen Anbausystemen," *Kühn-Archiv*, 1930, XXVI.

¹¹ The most comprehensive of the earlier studies made in the United States seem to have been those by C. G. Hopkins; see his *Soil Fertility and Permanent Agriculture* (New York, 1910).

¹² A. J. Perkins, "Wheat Yields Past and Future, with a Reference to the Principal Factors that Govern Them," *Journal of the Department of Agriculture of South Australia*, December 1916, XX, 377-99.

of declining, increasing, and stable fertility. Areas where soil fertility is increasing are used to a large extent for the production of crops other than grains. A large proportion of the land where fertility is declining rapidly, on the other hand, produces grain almost exclusively. In general, the less assured the situation with reference to long-time fertility, the more such land is devoted to grain production. Important differences can also be observed with regard to the proportions in which different grains are produced on soils of increasing, declining, or stable fertility. While wheat and especially barley are grown primarily on soils of declining fertility, rye and oats are largely produced on soils of stable or increasing fertility.

SOIL REQUIREMENTS OF THE GRAINS

Ranked according to their requirements as to quality of the soil, the several grains seem to occupy the following positions: wheat is the most exacting; barley comes next; and corn, oats, and rye, or corn, rye, and oats, follow in the order mentioned. Only a broadly general validity can be claimed for this ranking, which is derived from the more detailed discussion that follows. The soil requirements of each grain have certain peculiarities which cannot be taken into account in a broad generalization.

Wheat.—The soils which produce good yields are approximately the same for all grains except rice. They are rather heavy, deep, well-drained soils with plenty of nutrients in readily available form, free of weeds, and slightly alkaline to slightly acid. Former grassland is almost the sole origin of these soils. In many countries too cold for corn, the best soils are devoted primarily to wheat; accordingly, it is widely customary in western Europe to call these wheat soils. Wheat does not object vigorously to soils heavier than the optimum, if they are well drained; but it is rather difficult to keep heavy land in such condition. The strenuous efforts made in Germany and other countries to develop a variety of wheat which grows well on sand have thus far failed.

Wheat strongly prefers loamy soils with a considerable content of humus, although some soils containing next to no humus produce good wheat crops. It also yields better with active bacterial flora in the soil. The ability of wheat to extract nutrients from the soil when they are not in readily accessible form is only moderate. So is its tolerance toward acidity. On strongly acid soils containing neither nutrients in readily accessible form nor an abundance of active bacteria, wheat simply refuses to grow. Such expressions as "does not grow" and "refuses to grow" are frequently used only in a relative sense, but with regard to the production of wheat on poor soils these expressions must be taken literally. Very sour and strongly leached soils in their natural state do not return even the seed, and less strongly sour and less strongly leached soils frequently produce not much more than the seed. This behavior of wheat is of paramount importance for the competition of wheat with other grains, owing to the large proportion of strongly acid soils in the world and especially owing to the great expanses of extremely poor gray forest soils. A large portion of these soils in their natural state must be considered physically unfit for wheat production. A considerable part of the remainder is spread all the way between physically unfit and just under the competitive basis.

Practically no wheat was grown in the huge area comprising the non-chernozem zone of European Russia until a few years ago, and the recent strenuous efforts of the Soviet government to develop wheat growing there have thus far had only moderate success (see pp. 507-08). The area where wheat can be grown competitively only in occasional spots extends west from the non-chernozem region of Russia well into Germany. Farther west, owing to a large proportion of brown forest soils, wheat is not so handicapped; but much of the land now in wheat has become usable for this purpose only as a result of human effort extending over many decades and even centuries. On forest soils of the central and southern portion of western Europe as well as of the Danubian coun-

tries, the conditions seem less nearly prohibitive to growing of wheat than on the cold gray forest soils of northeastern Europe.

Many forest soils of the Middle Atlantic States likewise seem to belong to those of which one can justly speak not of the physical impossibility of growing wheat but of the competitive impossibility. The situation is even more favorable for wheat on the brown forest soils widely represented in the East Central States. The failure of wheat on such soils is frequently due exclusively to a strongly acid reaction, and application of lime removes the obstacle. The unsuitability of such soils for wheat in their natural state has nevertheless a great historical significance. Moreover, a considerable proportion of soils in these states cannot be made wheat soils simply by the use of lime.

Soils which in their natural state cannot produce any wheat in the absolute sense are found even in such a state as Indiana, where the soil ranks with the best in the United States and the world. On three experiment fields of that state (Moses Fell Annex Farm, Sand Field, and Jennings County Field), wheat on untreated plots averaged only 2.7 bushels per acre and on one even only 1.8 bushels, i.e., the land returned approximately only the seed. Corn is not the least modest with regard to soil requirements; yet on the same fields it produced eight times as much as wheat.¹³ On the Elizabethtown Field in Illinois, a state famous for its soil, wheat after corn in an 18-year average also yielded only 1.7 bushels per acre on untreated plots.¹⁴

No kind of wheat is very strong in combating weeds. Spring wheat, a slow starter, is particularly easily overcome by weeds. Freedom of the soil from weeds is therefore an important requirement for success in wheat growing. This peculiarity further limits the possibilities of wheat growing, since spring

¹³ *Reports of Progress of the respective farms or fields; see also Table 9, p. 233.*

¹⁴ F. C. Bauer and others, *Crop Yields from Illinois Soil Experiment Fields* (Illinois Agr. Exp. Sta. Bull. 425, July 1936), p. 211.

wheat and to a lesser extent winter wheat must cede to other grain crops part of the land on which the competitive position of wheat is otherwise strongest. Moreover, the very soils that are suited to the production of the most desirable wheats are those on which wheat has to admit other crops. In wide territories with good grassland soils, such as the Prairie Provinces of Canada and the hard-spring-wheat region of the United States, weediness is the main factor which makes inevitable the shift from continuous wheat to fallow and/or rotation crops on land which has been in culture for some time, even though wheat not excessively hampered by weeds yields the greatest profit or is the only crop which can yield a profit (see also the section on working the soil in chapter xiii). Infestation of the soil with weeds also plays a role in the competition of fall-sown wheat with fall-sown barley in California, and probably in some other regions with a similar climate, with wheat frequently on the losing end. Weediness of winter wheat has long been one of the important reasons for the wide distribution of rye on chernozem soils of southern Russia.

Barley.—Two-row barleys (the typical malting barleys) are more exacting than six-row barleys with regard to soil and other growing conditions. Unfortunately, reports on experiments frequently fail to point out to which specific kind of barley the statements and findings pertain.

Two-row barleys require soils practically as good as those best for wheat, but soils of somewhat lighter type are the optimum. Moreover, in the case of barley, the needed amount of "heaviness" of the soil can apparently be replaced by providing light soil with an ample supply of plant food more easily than is the case with wheat.¹⁶

¹⁶ The optimum soil conditions for two-row barley indicated in the text are for *best yields* of barley. Where *quality of the barley* is the prime consideration, the requirements are modified. J. A. S. Watson and J. A. More (*Agriculture; The Science and Practice of British Farming*, 2d ed., Edinburgh, 1928, p. 179) describe the growing of malting barley in England as follows: "The best soil is light, free, open in texture, and of a nature suitable for turnip growing and sheep farming; it is often thin and naturally poor and has to be kept in condition by feeding off the root crops. Probably the best barley is grown on the Chalk, Tertiary, and Recent deposits, and it is seldom that a good sample is obtained from heavy or high conditioned soil suitable for wheat."

An ample supply of plant food in readily accessible form is an indispensable requirement for successful growing of two-row barleys. Any barley has a smaller root system than any other grain, and barley is also particularly shallow-rooted. According to the experiments of Hellriegel pertaining to two-row spring barley, its roots made up 7.9 per cent of the total weight of the plant at maturity. The roots of spring oats as a percentage of the plant weight were half again as high.¹⁶

The importance of the small root system in barley is considerably augmented by the fact that barley has the shortest growing season of the five grains here studied (see pp. 252-53), and that within this short season the absorption of nutrients seems to be particularly strongly concentrated in the early period of growth. Berkner¹⁷ presents the following data on the distribution of the absorption of nutrients by spring barley by months, in kilograms per hectare, in support of his assertion that practically the whole supply of nutrients used by barley is absorbed within 60 days:

Month	Nitrogen	Phosphate	Potassium
April	6	2	6
May	32	19	48
June	30	12	28
July	7	4	5

The same authority observes that by the end of June spring barley overtakes *winter* rye with regard to the absorption of nutrients. Whereas spring barley in July needs 7 kilograms of nitrogen, 4 of phosphate, and 5 of potash, the requirements of winter rye are 15, 6, and 5 kilograms, respectively.¹⁸

Spring barley is a fast starter. Weediness therefore is not quite so large an obstacle as in the case of spring wheat. But the objection of barley to acidity is even stronger than that of wheat. In Woburn, part of the famous Rothamsted Experiment Station, the yield of barley from unmanured plots de-

¹⁶ Franz Schiadler, *Handbuch des Getreidebaus* (3d ed., Berlin, 1923), p. 409.

¹⁷ F. Berkner, "Der Getreidebau," *Handbuch der Landwirtschaft* (Berlin, 1928), III, 75.

¹⁸ *Ibid.*, pp. 38, 75.

clined in continuous cropping from 8.5 cwt. per acre on the average in 1877-1906 to 4.0 cwt. on the average of 1907-26. The decline for wheat was only from 7.1 cwt. to 4.7 cwt.¹⁹ Russell comments on page 45: ". . . the exhaustion of lime and production of acidity affected the shallow-rooting barley sooner than the wheat." At another point he states: ". . . the effects of the acidity [on wheat] were later in developing, owing to the circumstance that wheat is less sensitive than barley."²⁰

Results similar to those of Woburn were obtained in Agdell Field, Rothamsted, in a rotation of turnips-barley-wheat, which has been started as early as 1848. In the first twenty years, wheat on unmanured plots yielded on the average 17.8 centals while the yield of barley was 19.8 centals. In the second twenty years, wheat yielded slightly more than barley—12.7 centals as against 11.7. In the last twenty years, the average yield of barley was only 7.1 centals while that of wheat was 11.3 centals.²¹

Finally, let us note the data in Table 8, which are presented even though for small grains they apply to only two years. Their merit is that acidity is measured and a statement of the findings is included in the report. In very sour soil (pH 4.6), the yield of wheat was only 26.9 per cent of that obtained on an approximately neutral soil (pH 6.8). Yet the very sour soil produced some wheat while it yielded no barley at all. The decrease of the acidity to pH 5.0 enabled barley to grow, but from a practical point of view it was still a failure.^{21a}

The soil requirements of two-row barley are so specific that, were very much of these soils needed, they would be regarded as more valuable than the soils best adapted to

¹⁹ E. J. Russell and J. A. Voelcker, *Fifty Years of Field Experiments at the Woburn Experiment Station* (London, 1936), p. 140.

²⁰ *Ibid.*, p. 225.

²¹ A. E. V. Richardson, *Wheat and Its Cultivation* (already cited), p. 64.

^{21a} The barley grown in this experiment was a six-row barley, but the results apply to two-row barleys as well. Hitherto our data have referred to two-row barleys.

TABLE 8.—YIELDS OF GRAINS GROWN AT FIVE REACTIONS AT WOOSTER, OHIO, 1928-34*

Soil reaction pH	Corn (5 years)	Wheat (2 years)	Oats (2 years)	Barley (2 years)
(A) CENTS PER ACRE				
4.6	7.4	3.5	11.3	0.0
5.0	12.1	5.4	10.7	1.3
5.6	14.2	8.3	11.0	3.7
6.8	17.7	13.0	14.2	8.0
7.7	18.0	15.7	17.0	10.1
(B) RELATIVES, TAKING YIELDS AT pH 6.8 = 100				
4.6	41.8	26.9	79.6	0.0
5.0	68.4	41.5	75.4	16.3
5.6	80.2	63.8	77.5	46.2
6.8	100.0	100.0	100.0	100.0
7.7	101.7	120.8	119.7	126.2

* *Handbook of Experiments in Agronomy* (Ohio Agr. Exp. Sta. Spec. Circ. 46, June 1935), p. 55. Average of rotations of corn-small grain-soybean hay; and corn-small grain-timothy hay. The reaction is approximately neutral at pH 6.8, and figures lower than this indicate increasing degrees of acidity.

wheat growing. It was pointed out above that our ranking of wheat as the most exacting grain with regard to requirements of the quality of soil has important limitations.

The six-row barleys are able to extract nutrients from the soil more easily than two-row barleys. Hendry writes: "[Two-row barley] is more exacting in its soil . . . requirements than the common type [six-row barley], and is restricted to the stronger soils . . ." ²² Similarly, Hunter states: "*H[ordeum] vulgare* [common nodding six-row barley] can be grown successfully on poorer soils. . . ." ²³ But the expression "poorer" is valid only when the comparison is with two-row barleys or wheat. Even in its six-row varieties, barley remains a shallow-rooted, fast-growing plant which only re-

²² G. W. Hendry, *I. Cereal Hay Production in California*, F. W. Woll, *II. Feeding Trials with Cereal Hays* (Calif. Agr. Exp. Sta. Bull. 394, October 1925), p. 24.

²³ Herbert Hunter, *The Barley Crop* (London, 1926), p. 19. No distinction between four-row and six-row barleys is here considered necessary.

luctantly makes use of plant food not in easily accessible form.²⁴

In rapidity of growth the six-row barleys exceed even two-row barleys. An experiment on the yield of cereal hay at different stages of maturity in California shows clearly the extent to which accumulation of nutrients by such barley is ahead of that of the other small grains. The grains tested were Coast barley,²⁵ White Australian wheat, California Red oats, and an unidentified rye. All grains were sown in the fall. The yield of hay in tons per acre was as follows:²⁶

Stage when cut	Barley	Wheat	Oats	Rye
Blossom	5.40	6.32	5.95	5.20
Milk	5.70	7.65	8.22	7.77
Soft dough	5.57	8.20	8.32	7.27
Ripe	4.40	7.42	7.35	7.22

The blossom stage was reached 40, 36, 41, and 49 days before maturity, respectively, in the order of grains tabulated. At that stage, the weight of the barley plant, having been cut and dried, was within 5 per cent of its maximum weight. The other cereals all made large gains in weight after blossoming.

Real six-row *winter barley* displays characteristics similar to six-row spring barley. Remy²⁷ describes the difference between the seasonal curve of the absorption of plant food by winter barley and winter rye as follows: "Winter barley sown at the proper time distinguishes itself from rye by larger absorption in the fall and an absorption in the spring and summer that starts later, ends earlier, and thus is more concentrated seasonally."

²⁴ Some six-row barleys, however, seem to be really very modest in their soil requirements. Otto v. Frangeš, *Die sozialökonomische Struktur der jugoslawischen Landwirtschaft* (Berlin, 1937), p. 27, describes barley grown in a portion of his country as a very modest grain crop which is satisfied with red soil poor in nutrients. I. E. Nagy, *Die Landwirtschaft im heutigen Ägypten* (Vienna, 1936), characterizes barley grown in Egypt as very modest in its soil requirements. Some of the barleys grown in British India and certain other countries also seem to possess the same characteristics.

²⁵ Coast barley is a six-row spring barley, which is fall-sown in California.

²⁶ Hendry, *op. cit.*, Tables 9 and 11, pp. 46-47.

²⁷ Th. Remy, *Ernährung der Pflanze* (Berlin, 1931), p. 306, as cited by Gerhard Quitrau, "Nährstoffaufnahme bei Wintergetreide," *Kühn-Archiv*, 1932, XXX, 327.

To acidity, six-row barleys seem to be as sensitive as two-row barleys; but they prove superior to other grains on alkaline soils. Table 8 shows for six-row barley in Ohio that its yield on alkaline soil (pH 7.7) was much larger than on approximately neutral soil (pH 6.8); the yield of corn, however, remained practically the same. The increases in yields of wheat and oats, it is true, were almost as large as that of barley. These data fail to reflect in full the material superiority of barley on alkaline soils; on very alkaline soils barley is the only grain which will produce a crop.

Since six-row barleys are stronger "feeders" than two-row barleys, their resistance to weeds is even greater. In the portion of the Great Plains growing spring wheat, six-row barleys are used as a "cleaning crop."²⁸

Corn.—The principal requirement of corn with regard to soil seems to be a sufficiently deep soil which can be penetrated easily by the roots. Corn, therefore, shows a definite dislike for very heavy top soil or subsoil. It can be grown on much lighter soils than either wheat or barley. Carleton²⁹ even goes so far as to say that "many very sandy soils are not at all suitable for the small grains, though they may be good for maize, sorghums, and legumes."³⁰

Unlike wheat and barley, corn can utilize to advantage plant food not in readily accessible form. Data in Table 9 clearly demonstrate the much greater ability of corn, as compared with wheat, to thrive on poor soil.³¹ It has been stated that "Sandy soils, unless heavily manured, are not desirable for corn, as they dry out quickly and are usually low in fertility."³² Such a statement should not be taken to mean that

²⁸ "This practice, however, does not favor the maximum production of barley, and because of the unfavorable competition from weeds, may result in a reduced and disappointing yield." T. E. Stoa, *Barley Production in North Dakota* (North Dakota Agr. Exp. Sta. Bull. 264, January 1933), p. 4.

²⁹ M. A. Carleton, *The Small Grains* (New York, 1920), p. 233.

³⁰ Rye, a rather unimportant crop in the United States, seems to have escaped the attention of the author when he made this statement.

³¹ Similar results are obtained from a comparison of the yields from experimental fields of different fertility in Illinois.

³² H. A. Wallace and E. N. Bressman, *Corn and Corn Growing* (3d ed., New York, 1928), p. 65.

TABLE 9.—AVERAGE YIELDS OF CORN AND WHEAT ON EXPERIMENTAL FIELDS IN INDIANA*

Field	Centals per acre		Wheat yield as per cent of corn yield
	Corn	Wheat	
Moses Fell Annex Farm.....	11.3	1.9	16.8
Sand Field	12.5	1.1	8.8
Jennings County Field	15.8	1.8	11.4
<i>Average</i>	<i>13.2</i>	<i>1.6</i>	<i>12.1</i>
Huntington Field	18.1	7.7	42.5
Purdue-Vincennes Farm	18.4	6.4	34.8
Herbert Davis Farm.....	19.2	6.2	32.3
<i>Average</i>	<i>18.6</i>	<i>6.8</i>	<i>36.6</i>
Lafayette Farm	22.7	11.0	48.5

* Data from *Reports of Progress* of the respective farms or fields. The first group includes the three fields with corn yields of less than 30 bushels (16.8 centals) per acre, the second group the three with corn yields of 30-40 bushels (16.8-22.4 centals) per acre. Data are mostly averages for 15 years or more, ending with 1934; for yields of untreated plots in the general fertility tests of most fields; of the rotation corn-wheat-hay, except at Huntington where it was corn-oats-wheat-hay.

it would be more profitable to turn these lands to some other crops. No such crops are available over wide territories. The statement is evidently intended as advice to provide the soil with plenty of plant food in climatic conditions favorable for corn, for in these conditions it is usually able to repay the outlay generously.

Corn is much more a soil-depleting crop than any of the small grains. From these it does not differ much in the amount of nutrients needed per unit of grain, except in drier regions where its requirement is the largest. But the waste of nutrients—especially of nitrogen—through leaching, excessive aeration, and erosion is materially larger with corn, a crop grown in widely spaced rows, than with small grains. Since corn also yields more, soil depletion of nitrogen by corn may be several times that caused by small grains, where crops are grown without fertilizer in any form.

It is a rather generally accepted opinion that corn is less sensitive to acidity than either wheat or barley (see Table 8).

According to Bear,³³ corn (and buckwheat) are tolerant to acidity, while barley and wheat are sensitive. But Worthen³⁴ places barley in the group of moderately tolerant grains, while corn and wheat are in the medium group in his arrangement of five degrees of tolerance—slight, moderate, medium, strong, and very strong.

Finally, the much lesser difficulty of growing corn on very rough land should be mentioned here. Owing to this, corn "has come in many parts of the world to be the mainstay of primitive or isolated hill peoples."³⁵

Oats.—Oats are successfully grown on all kinds of soil but hold the strongest position on very heavy soil. Very light soil does not suit oats well, owing partly to their larger water requirement.

Oats need large amounts of nutrients per unit of weight of grain. The requirement may be less only as compared with corn, where this grain has a very high proportion of stover to grain. In English conditions, spring oats need about 15 per cent more nitrogen, phosphoric acid, and potassium combined per unit of weight of grain than winter wheat, and spring barley needs about 25 per cent less than spring oats.³⁶

Oats, however, are commonly recognized as a strong feeder; they can therefore be grown on soils with the least amount of readily accessible plant food.³⁷ One reason is the

³³ F. E. Bear, *Theory and Practice in the Use of Fertilizers* (2d ed., New York, 1938), p. 301.

³⁴ E. L. Worthen, *Farm Soils, Their Management and Fertilization* (2d ed., New York, 1935), p. 221.

³⁵ J. R. Smith, *Industrial and Commercial Geography* (New York, 1913), p. 83.

³⁶ E. J. Russell, *Soil Conditions and Plant Growth* (7th ed., London, 1937), p. 550. The difference is brought about primarily by the difference in the content of potassium, which in oat straw is about twice as large as in wheat and rye straw and is equaled only by the content of potassium in corn stover.

³⁷ Prjanischnikow regards oats as even less exacting with regard to soil than rye, and ranks it last after wheat, barley, millet, and rye (a ranking that does not include corn). See D. N. Prjanischnikow and I. W. Jakushkin, *The Field Crops* [translated title] (9th ed., Moscow, 1936), p. 57. Since Jakushkin merely brought Prjanischnikow's famous work up to date for this edition, the book is cited under the name of the senior author throughout. Occasionally there was need of citing an earlier edition of the same work. In such cases we have used the German edition (*Spezieller Pflanzenbau*, Berlin, 1930) which is always made recognizable in the quotation.

larger and deeper root-system as compared with barley.³⁸ Furthermore, the growing season of oats is longer than that of barley, especially in moister climate. Also, the process of absorption of nutrients is spread more evenly over the growing period. Table 8 (p. 230) shows that oats are far less susceptible to acidity than barley, wheat, or corn. Oats surpass even rye in this respect, according to Prjanischnikow.³⁹ Frequently called "the plant of the moors," the oat plant justifies this designation.

The great ability to utilize plant food not in readily available form, and the slight sensitiveness of the plant to acidity, assure oats an important place in the vast regions of poor, leached, and acid podsols in northern and northeastern North America and Europe, as sketchily enumerated in the first section of this chapter. The same property permits oats to be grown in the place in rotation where the soil is in poorest condition.

There is another important reason why oats are widely grown: they are rather grateful for an ample supply of plant food.⁴⁰ Oats frequently prove superior to wheat, if the difference between yields of grain obtained on poorer and better soils is measured in quantities rather than in percentages. The ability of oats to do well on fertile soil is especially important in the competition of oats with rye, which is less efficient than oats in this respect and does not fetch sensibly higher prices as does wheat.

Rye.—"Rye is less exacting in its soil requirements than any of the other important cereals," according to Morgan.⁴¹

³⁸ The comparisons found in the literature are usually between these two grains, which most frequently compete for the same place in rotations.

³⁹ D. N. Prjanischnikow, *The Field Crops*, p. 58. But E. L. Worthen (*loc. cit.*) includes oats together with corn and wheat in the group of plants of medium tolerance.

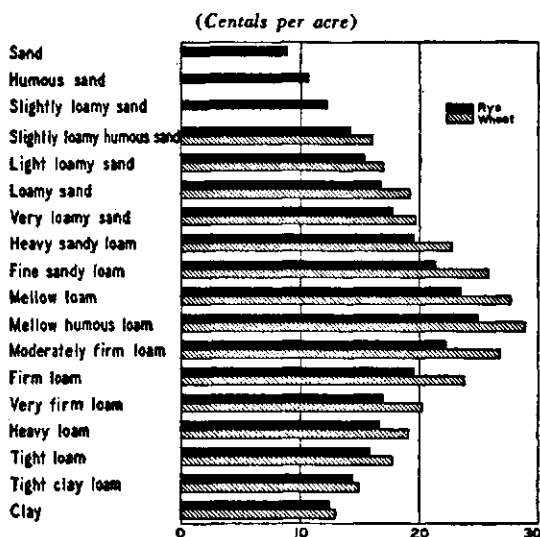
⁴⁰ See, for example, F. Schindler, *op. cit.*, p. 408; also the sections on manure and commercial fertilizer in chapter xiii.

⁴¹ M. F. Morgan and others, "The Soil Requirements of Economic Plants," *Soils & Men, Yearbook of Agriculture, 1938*, p. 759. See also W. W. Talanow and W. P. Kusmin, "The Requirements of Individual Crops as to Growing Conditions and the Possibility of Their Expansion and Shifts to Certain Regions of the USSR," *The Crops of the USSR* [translated title] (Leningrad and Moscow, 1933), p. 67.

On very heavy soils, it does not do so well as oats but does relatively better than wheat and barley. It is better suited to very light soils than is any other small grain; and this is very important for the position of rye in world grain production. Rye may not be quite so tolerant to acidity as oats, but in this respect it surpasses barley, wheat, and corn. In fact, rye withstands acidity enough to be grown on wide stretches of former forest lands in northern and northeastern North America and Europe, upon which wheat and barley cannot be expected to do well. Soils too sour for rye are not much used for crop production anyway. Rye, however, is less responsive to a plentiful supply of plant food than any other grain studied here. This strongly limits its competition on better soils.

Chart 23 demonstrates the relation between the composition of the soil and the yields of winter wheat and winter rye in Germany, according to Sagave. The data seem to be esti-

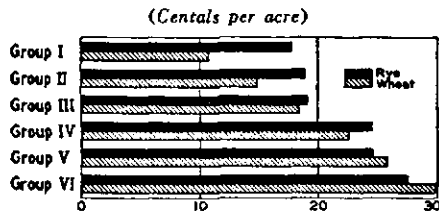
CHART 23.—RELATION BETWEEN COMPOSITION OF THE SOIL AND YIELDS OF RYE AND WHEAT WITH AVERAGE CLIMATE*



* Based on data in Sagave, *Grundzüge der Abschätzungslehre* (Berlin, 1934), quoted from F. Scheffer, "Wege und Ziele der deutschen landwirtschaftlichen Bodenkunde," *Kühn-Archiv*, 1935, XXXIX, 151. "Average climate" evidently applies to Germany.

mates, but are probably based on adequate evidence. Sagave undoubtedly assumed that the land was limed, if necessary, and provided with all the fertilizer it needed in order to produce good yields; this is indicated by the heavy yields of both wheat and rye. No yields of wheat are given for the three lightest types of soils. Soils which, with all the care assumed by the author, yield only 9 to 12 centals of rye per acre under German conditions cannot profitably be used for wheat. On all other soils, wheat outyields rye, according to Sagave.⁴² As the soils become heavier, the yield of wheat increases considerably more than that of rye. On the best soils, neither light nor too heavy, wheat outyields rye by no less than 4 centals per acre.⁴³ On still heavier soils, the yields of both wheat and rye decline, and the decline in yield of wheat is the more rapid one. On the heaviest soils, wheat yields barely more than rye.

CHART 24.—YIELDS OF WINTER RYE AND WINTER WHEAT ON SOILS OF DIFFERENT QUALITY, IN 48 EXPERIMENTS IN EASTERN GERMANY*



* Basic data from W. Heuser, "Wintergetreideversuche in Ostdeutschland," *Landwirtschaftliche Jahrbücher*, 1932-33, LXXVI, 345-47. The tests were made in the Grenzmark Posen-West Prussia, East Prussia, Brandenburg, Pomerania, and Silesia. They are distributed among six groups according to the yield of wheat.

Sagave's estimates agree well with the results of experiments conducted in eastern Germany and summarized in Chart 24. The information as to the method of arranging the

⁴² It seems somewhat optimistic to expect higher yields of wheat from a type of soil (slightly loamy humus sand) that is only slightly heavier than the type from which the yield of wheat is considered not worth mentioning.

⁴³ On a percentage basis, the difference in yields increased from 12.5 per cent in favor of wheat on slightly loamy humus sand to 21 per cent on mellow humus loam.

tests is somewhat vague. Heuser, the reporter, merely states that each kind of grain received the kinds and amounts of fertilizer and care that were considered best for it. The fact that, according to his statement, the cost of production of wheat was larger than that of rye may indicate that wheat received more fertilizer, care, or both. But the soils of the regions where the experiments were performed greatly favored rye. Even so, rye outyielded wheat by only 9 per cent on the average. In Group I, it is true, the yield of rye exceeded the yield of wheat by more than 50 per cent. But with improvement of the growing conditions, the yield of rye increased slowly, whereas the yield of wheat increased rapidly. In Group V, wheat had already overtaken rye; and in Group VI, it yielded approximately 10 per cent more. Differences in soil must have been the principal reason bringing about those variations in relative yields. Yet the arrangement of the results according to yield of *wheat* detracts from the usefulness of the data.

The modest soil requirements of rye are most pronounced in spring rye, which is therefore preferably grown in the most precarious conditions of soil and climate such as are found, for example, in the Baikal region of Siberia.⁴⁴

⁴⁴ W. W. Talanow and W. P. Kusmin, *op. cit.*, p. 68.

CHAPTER XI

TEMPERATURES

Grain is grown north of the arctic circle and within the tropical zone, at sea level and at elevations up to some 15,000 feet. Between these extremes grains compete with other crops as well as with one another under a wide range of temperature conditions—from a frost-free period extending over the whole year to one of less than 100 days, from an amount of warmth hardly sufficient to support any vegetation to so much heat that only a few plants can withstand it. The competitive power of one grain with another inevitably shows large variations under these manifold temperature conditions. Winter-hardiness, minimum heat requirement, minimum germinating temperature, length of growing period, and resistance to heat are the principal factors involved. Preliminary to detailed discussions of these, a brief summary of their significance for each of the five grains is pertinent.

The area where corn can be grown is greatly limited, for corn has no winter-hardiness, far exceeds the other grains studied here in its minimum heat requirement, and has a longer growing period than any spring-sown small grain. Corn resists heat, especially moist heat, relatively well, but the resulting advantage is counteracted by the ability of some of the competing small grains, and of all of them in certain regions, to avoid the worst summer heat by being sown in the fall.

Barley has the shortest growing period, requires no more warmth than any other small grain, and hence can penetrate farthest north. It is superior to other small grains in resistance to dry heat. But its competitive power is greatly limited by the fact that it is much less winter-hardy than wheat.

Oats, though a cool-weather plant, resist heat, especially moist heat, comparatively well; but they are even less winter-hardy than barley.

Rye, another cool-weather plant, seems to be little adapted to either dry or moist heat. Its main asset is that it is superior to any other grain in winter-hardiness.

Wheat has a longer growing period and a somewhat higher minimum heat requirement than any other of the small grains. It is inferior to barley in resistance to dry heat and seems not to be always superior to oats in this respect. Its principal advantage is winter-hardiness, in which it is inferior only to rye.

WINTER-HARDINESS

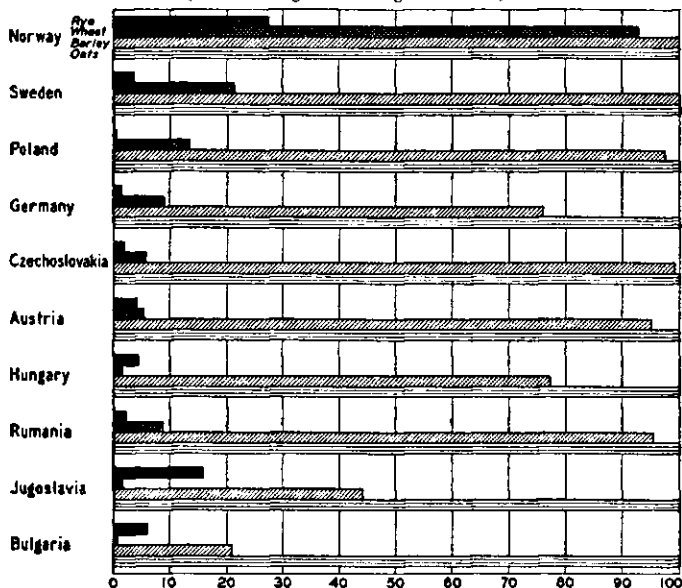
Winter-hardiness can be defined as ability to survive the winter without much loss. It is a phenomenon not only of temperature but also of precipitation. The absence of snow cover and insufficient or excessive moisture in the fall greatly reduce this ability. Yet the discussion of the differences between the grains in winter-hardiness belongs in this chapter because temperature is the principal factor. Ability to withstand heavy frosts is a very important feature of winter-hardiness, while high fall temperatures reduce winter-hardiness by stimulating excessive growth and the development of fungus. Alternate changes from light frost to thawing bring about heaving of the plants.¹

Although corn has migrated far from its original home somewhere in the tropics, it has nevertheless preserved several important habits of plants of hot climates. One is that corn possesses no winter-hardiness; hence no more need be said of it here. Each of the other four grains requires discussion in respect to this factor. Certain aspects of the advantages of winter-hardiness, however, will be discussed in the later section dealing with heat resistance, since one of the principal advantages of fall-sown grains is that, if so sown, the plant avoids the maximum summer temperatures.

¹The fact that fall-sown grain perishes not only through direct influence of frost but through specific winter diseases should be mentioned. The fungus "*fusarium nivale*" grows on winter grains especially when they have developed exuberantly in the fall and are covered in the spring with much snow. In the forest climates of northern Europe this is the main cause of losses, especially in some years. It has led to the disinfection of the seed against *fusarium*, a costly and tedious procedure. It also leads to very late seeding and to occasional grazing down of the fields before winter.

CHART 25.—PROPORTION OF SMALL GRAINS SPRING-SOWN IN SPECIFIED EUROPEAN COUNTRIES, 1935*

(Total acreage in each grain = 100)



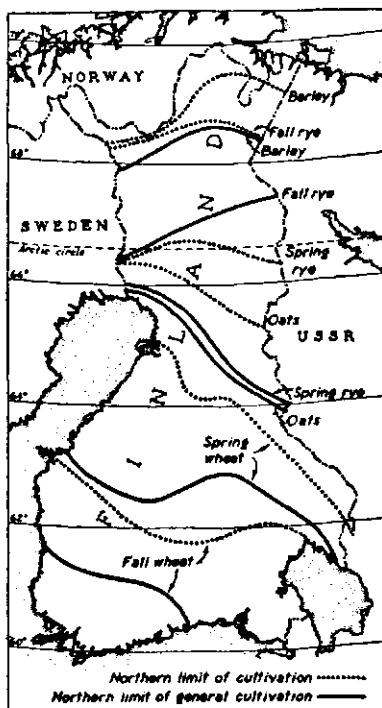
* Data in Table IV.

Rye.—Rye far exceeds all other grains in winter-hardiness. It is grown almost as far north as grain growing extends. Indeed, the regions where winter rye² does not survive play only a minor role as grain producers. Consequently, there is little occasion for growing spring rye, which yields considerably less and is also inferior in quality.

In Europe, winter rye reaches the 65–67° parallel, while grain growing extends to about the 70° parallel. Even in Norway, the northernmost European country, only 27.5 per cent of the rye acreage was in spring rye in 1935 (Chart 25).

² The expressions winter and spring grain are not always used in strictly the same sense. Botanically, the terms imply different specific habits. Crop statistics, however, designate as winter grain any grain sown in the fall or winter, even if the grain so sown is of spring habit. The writer has used the expression winter grain wherever he was sufficiently positive that the grain referred to must be of winter habit, and the expression fall-sown in cases when all or part of the grain so sown may be of spring habit. Any spring grain possesses little if any ability to withstand cold, while winter grain needs the frost stimulation in order to "shoot" into stalks. The discussion in this chapter pertains therefore specifically to winter grain.

CHART 26.—NORTHERN BOUNDARIES OF GRAIN CULTIVATION IN FINLAND*



* Adapted from Chart 24¹⁶ in Geographical Society of Finland, *Atlas of Finland* (Helsingfors, 1925-28).

In Finland, with a more severe climate than that of Norway, the northern limit of winter rye practically coincides with the arctic circle ($66^{\circ} 32'$), as shown in Chart 26. As indicated by the chart, in Finland spring rye does not extend as far north as winter rye; this may be due to failure to use varieties of spring rye that have the shortest growing period. In any case, apparently little or no spring rye is grown.³

The size of the zone designated "Barley-Spring Rye" in the map showing the crop zoning in European Russia (Chart 22, p. 217) may give the impression that spring rye is rather important in Russia. The area where winter rye cannot grow is indeed rather large, but it consists mostly of forested

land and of swamps, where very little grain is produced. Spring rye is grown much more extensively in Siberia than in European Russia, yet the total Russian acreage in spring rye amounted to only 1.5 per cent of the total rye acreage in 1935 (Table IV). The small quantities of spring rye found in the other European countries partly represent resowings of winterkilled rye. Some of the rye grown there at high elevations, especially on extremely poor land, may be spring rye. Some may have its explanation in the backwardness of the producers (Yugoslavia).

³ Finnish crop statistics do not separate spring and winter rye, while separating spring from winter wheat.

In North America, difficulties in growing winter rye seem to be encountered only in the far north of the Canadian grain belt. In the northernmost crop-reporting district of Saskatchewan, the area in spring rye was ten times as large as that in winter rye in 1934 (18,500 acres of spring rye to 1,800 acres of winter rye); but only 68,500 acres of spring rye were sown in the whole province as against 278,000 in winter rye. The acreage in spring rye in all Canada is equivalent to about 20 per cent of the total area in rye. Part of this acreage may represent resowings of winterkilled rye. In the United States, the growing of spring rye seems to be limited to north central Montana.

The 1.6 million acres in spring rye specified in Table IV represent approximately the world total. Of the world acreage in all rye, equivalent to about 100 million acres, spring rye makes up less than 2 per cent.

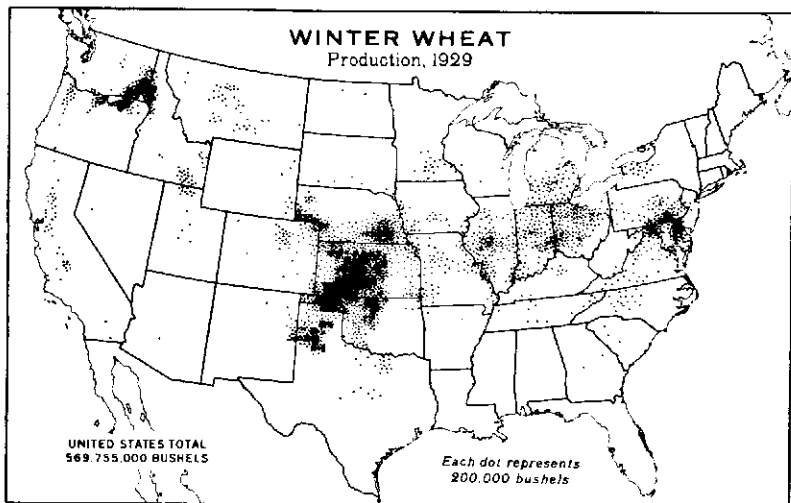
Wheat.—Wheat is much less winter-hardy than rye. In western Europe, winter wheat can be grown everywhere, but in central Europe and even more so in the eastern parts of Europe, Siberia, and North America, insufficient winter-hardiness of wheat considerably affects its competition for the land. Almost the whole wheat acreage of Norway, small as it is, consists of spring wheat. Winter wheat can be grown only in the southwestern corner of Finland (Chart 26), and spring wheat makes up two-thirds of the wheat acreage. In the Baltic states and part of Poland the climate is also rather severe for winter wheat. All of Germany grows winter wheat; but in the east varieties with a rather large degree of winter-hardiness must be used, and winter-hardiness seems to correlate inversely with yields. The relatively small yields of winter wheat under such conditions increase the competitive power of spring wheat (a large part of the relatively small German acreage in spring wheat is located in eastern Germany) but also of winter rye.

In western Russia, soil is a more important limiting factor for winter wheat than temperature. Winter wheat extends northward hardly beyond the chernozem zone (see Chart 22,

p. 217), although hardy varieties of winter wheat could be grown successfully farther north if the quality of the soil permitted. Farther east, however, the production of winter wheat is more and more hampered by temperature. While the northern borderline of the chernozem zone has a northward inclination from west to east, at Kharkov, the former capital of the Ukraine, the northern borderline of winter wheat turns sharply southeast at Rostov almost touching the Azov Sea. The climate of North Caucasia permits the growth of winter wheat. But all the immense territory of the chernozem zone located to the north and east of the specified line in both European and Asiatic Russia can grow only spring wheat. Hence fully two-thirds of the Russian wheat area is in spring wheat. Moreover, even where winter wheat is grown, it is under the handicap of the requirement of varieties with great winter-hardiness, more so in the east than in the west. Severe winterkilling occurs from time to time in spite of the use of very winter-hardy varieties. The requirement of large winter-hardiness, and its interference with attainment of the highest yields, constitute a serious problem also in some countries west of the Russian wheat belt, for example, in part of Hungary and Rumania.

All the Atlantic states of this country, except in the far north, can grow winter wheat, and the losses through winterkilling are moderate owing to a reasonably good snow cover. But no winter wheat is grown north of them in Canada. In the principal Corn Belt states, winter wheat is mostly stopped at the southern border of the Great Lakes (Charts 27 and 28). But the states in the northern row—Ohio, Indiana, and Illinois—not infrequently experience severe losses from winterkilling, the average abandonment exceeding 10 per cent. A favored portion of the province of Ontario, Canada, grows some winter wheat. In the North Pacific States, winter wheat extends practically to the Canadian border, but at the expense of even higher average abandonment (owing primarily to lack of moisture) than in the northern string of Corn Belt

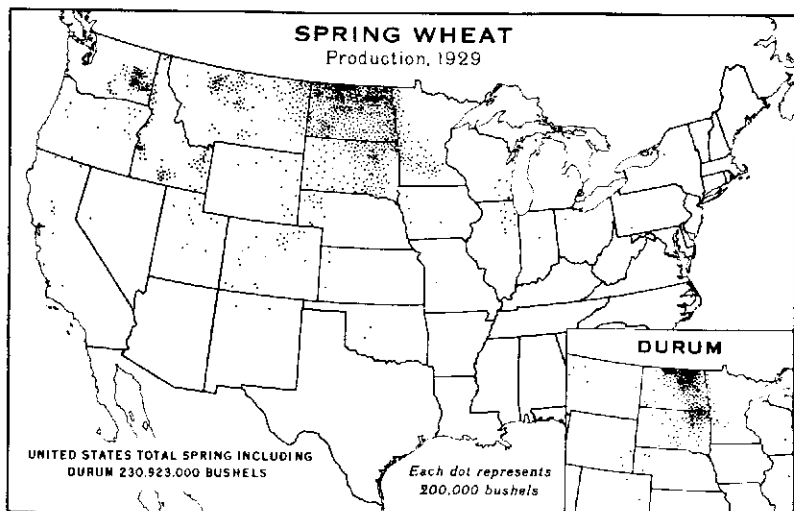
CHART 27



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CHART 28



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states.⁴ Montana succeeds in growing some winter wheat in the west and center (about $\frac{5}{6}$ of the wheat acreage of that state is sown to spring wheat), but only with an average abandonment exceeding 25 per cent of the sown acreage.

In the Great Plains, one of the two principal wheat areas of the world, winter wheat is stopped almost entirely before the northern border of Nebraska is reached.⁵ Moreover, abandonment is important as far south as southern Texas. In all of western Canada, winter wheat is grown in a few "oases" having sufficient snow cover. In the whole of the United States, spring wheat occupies about 30 per cent of the total wheat acreage, while in Canada only 2 to 3 per cent of the total—most of this in Ontario—is in winter wheat.

Thus the two most important wheat regions of the world, the grassland belt of the United States and Canada and that of Russia, are to a large extent deprived of the opportunity to grow winter wheat. Although in the rest of the world little spring wheat is grown, not less than around 40 per cent of the world wheat acreage (ex-China) has been devoted to spring wheat in recent years.

Barley and oats.—The statistics of rye and wheat production provide a fairly good picture of the limits of the competitive growing of winter rye and winter wheat. Where statistics show that only spring rye and spring wheat are grown, winter rye and winter wheat usually do not survive. The situation is somewhat different with regard to barley and oats. In most of Europe hardly any of the domestic winter barleys are used for beer, because these are the more winter-hardy six-row barleys (p. 53). Hence to grow winter barley under these conditions means that the producer must forego the chance of getting more than the price of feed grain. Much spring barley, therefore, is grown in regions where climate is no obstacle to winter barley. As to winter oats, we have the impression

⁴ Abandonment averaged 14.8 per cent in Washington in 1919-28. Actually, as elsewhere, there is little abandonment in most years but a heavy one once in a while. See J. S. Davis, "Pacific Northwest Wheat Problems and the Export Subsidy," *Wheat Studies*, August 1934, X, 372, 416.

⁵ Only about 6 per cent of the wheat acreage in South Dakota is fall-sown.

that the higher yielding capacity of winter grain over spring grain does not apply with the same force to them, at least in some regions.⁶ Watson and More⁷ say of conditions in Great Britain: "The yield of straw [of winter oats] is generally greater than that of spring oats and the yield of grain is quite up to the average."⁸ Whatever the reason, growers seem not to make use of the climatic possibility for growing fall-sown rather than spring-sown oats so eagerly as they do in the case of rye and wheat. In Australia, for example, a great deal of oats apparently is seeded in spring. Managerial considerations but also lack of knowledge may have something to do with this phenomenon in some cases. Even official statistics pay little attention to fall-sown barley and particularly to fall-sown oats, and frequently fail to separate them in totals (see Table IV).

Barley is so greatly inferior to wheat in winter-hardiness that, as in the case of rye and wheat, the difference is of great significance. Little, if any, winter barley is grown in Great Britain. About one-third of the barley acreage in the Netherlands is winter barley. Some winter barley is grown in Belgium, but climatic conditions probably would permit all the spring barley to be replaced by winter barley. But winter barley cannot be grown in north central Europe, and in central Europe it can be grown only in favorable localities. Germany and Hungary have only about 25 per cent of their barley acreage in winter barley, Yugoslavia around 50 per cent (Chart 25, p. 241). Fall-sown barley, in fact, becomes domi-

⁶ The reason may be, as pointed out by one of our advisors from Kansas, that winter oats are subject to loss from fungus diseases to a greater extent than the other grains.

⁷ J. A. S. Watson and J. A. More, *Agriculture; The Science and Practice of British Farming* (already cited), p. 162.

⁸ But according to D. D. Hill (*Oats Production in Western Oregon*, Oregon Agr. Exp. Sta. Bull. 285, June 1931, p. 7), "The yield of winter oats is relatively high in comparison with spring oats and the feeding value is usually excellent." According to T. R. Stanton and F. A. Coffman (*Fall-Sown Oat Production*, U.S. Dept. Agr. Farmers' Bull. 1640, November 1930, p. 3), "Usually fall-sown oats produce larger yields and grain of better quality." The difference may be due to differences in temperatures. Spring oats are not handicapped by high temperatures in Great Britain but are hampered in most regions of the United States adapted to winter oats.

nant only as far south as Bulgaria, where only around 20 per cent of the barley acreage is spring-sown. But in Rumania, with its more severe climate, only 5 per cent of the barley is winter barley, and none is grown in Russia north of the Black Sea.⁹ Thus the growing of winter barley on a substantial acreage in Europe is mainly confined to the three peninsulas in the Mediterranean.

In North America, the northern borderline of winter barley in the east passes through Delaware, Maryland, Virginia, Kentucky, southern Missouri,¹⁰ and westward through southern Kansas.¹¹ Winter barley can be grown all along the Pacific Coast, and it extends also into southern Idaho.¹² California, however, is the only region in the United States which, owing to its moisture conditions, makes an extended use of the possibility of growing fall-sown barley. Hardly more than 15 per cent of all barley¹³ grown in the United States, and probably less, is fall-sown.

But the small quantities of fall-sown barley produced in Europe and North America are materially augmented by the production in other continents. North Africa, British India, and Japan are heavy producers of barley, and all of it is fall-sown (or winter-sown). The proportion of fall-sown barley to the total world acreage of barley may be approximately 30 per cent.

Oats are the least winter-hardy of the four major small grains. Of the European countries shown in Table IV, only

⁹ Half of the small Russian acreage in winter barley is found in Azerbaidjan, in Transcaucasia.

¹⁰ M. A. Carleton, *The Small Grains* (already cited), p. 140. According to H. V. Harlan and others (*Tests of Barley Varieties in America*, U.S. Dept. Agr. Bull. 1334, November 1925, p. 158), some winter barley is grown commercially in Ohio, and there is even a small acreage as far north as Michigan.

¹¹ According to A. F. Swanson, *Pasturing Winter Wheat in Kansas* (Kansas Agr. Exp. Sta. Bull. 271, January 1935), p. 17, the use of winter barley in Kansas, except in the southern parts, is limited because of winterkilling, especially in the northern and western sections of the state.

¹² Harlan and others, *op. cit.*, as well as H. V. Harlan and others, *Yields of Barley in the United States and Canada, 1927-31* (U.S. Dept. Agr. Tech. Bull. 446, March 1935).

¹³ Including that used for pasture and hay. See C. V. Piper and others, "Our Forage Resources," *Agriculture Yearbook, 1923*, pp. 311-412, esp. pp. 355-56.

France accounts separately for fall-sown and spring-sown oats. Of the French oats acreage, 27 per cent was fall-sown in 1935. In most other European countries, either fall-sown oats are not grown or the acreage is so small that the statisticians do not consider it worth while to give separate figures. In the Rhineland, Germany, with its mild oceanic winter, all attempts at growing and breeding winter oats failed definitely. Winter oats survive in southern Yugoslavia and probably in a large portion in Bulgaria, but apparently none is grown in either country in appreciable quantities.¹⁴ Production of fall-sown oats in Europe seems to be concentrated in the two western peninsulas.

The United States is one of the countries where crop statistics do not show fall-sown oats separately. In the circular of the U.S. Department of Agriculture devoted to *Seedtime and Harvest* the following statement appears:¹⁵ "Winter oats are grown mostly where the average winter temperature exceeds 35 degrees, and hence are important only in regions south of the Ohio and Potomac rivers and along the Pacific coast."¹⁶ Abandonment is heavy in part of the delineated area. The total acreage in fall-sown oats in the United States, including that grown for pasture and hay, probably lies between 2 and 3 million acres, some 6 to 8 per cent of the acreage in oats.¹⁷ Similarly small is the fall-sown acreage in the world as a whole, although the oats grown outside of Europe and North America are largely fall-sown.

MINIMUM GERMINATION TEMPERATURE

Corn, which cannot be sown in the fall except in or near the tropics, needs a well-warmed soil to germinate and is sensitive to frosts when the young plant is still tender. The mini-

¹⁴ See, for Yugoslavia, Otto v. Frangeš, *Die sozialökonomische Struktur der jugoslawischen Landwirtschaft* (already cited), p. 34.

¹⁵ O. E. Baker and others, *Seedtime and Harvest* (U.S. Dept. Agr. Circ. 183, March 1922), p. 22.

¹⁶ See also the map on p. 2 of T. R. Stanton and F. A. Coffman, *op. cit.*

¹⁷ *Ibid.*, p. 1.

imum germination temperature of corn materially exceeds that of all other grains except millet, which requires approximately the same temperature, and sorghum, which needs a still higher temperature. According to Haberlandt,¹⁸ the minimum, optimum, and maximum germination temperatures of certain grains are as follows, in degrees centigrade:

Grain	Minimum	Maximum	Optimum
Wheat	3-4	30-32	25
Rye	1-2	30	25
Barley	3-4	28-30	20
Oats	4-5	30	25
Corn	8-10	40-44	32-35
Millet	8-10	40	32-35

The findings of Pammel of the Iowa Station indicate a still higher maximum germination temperature for corn. His figures are: minimum, 49.9° F. (10° C.); optimum, 91.4° F. (33° C.); and maximum, 134.8° F. (57° C.).¹⁹ On the other hand, some investigators indicate even lower minima for wheat, barley, and oats than those given by Haberlandt.

The differences in the minimum germinating temperatures between the four small grains, if any, are of no large import. But the high minimum germination temperature of corn and the danger of damage to the young corn seedings from late frosts necessitate late planting of corn. For example, in the north of the Corn Belt, seeding of spring wheat begins 30 to 40 days before the planting of corn.²⁰ This postponement is the more important, as corn has a longer growing period than any spring-sown small grain (p. 253).

FROST-FREE AND GROWING PERIODS

The average length of the period between the last killing frost in the spring and the first killing frost in the fall is of material import for the competition among grains. Corn is especially handicapped by insufficient length of the season,

¹⁸ Quoted from D. N. Prjenschnikow, *The Field Crops* (already cited), pp. 26-27.

¹⁹ Quoted from H. A. Wallace and E. N. Bressman, *Corn and Corn Growing* (already cited), p. 171.

²⁰ O. E. Baker and others, *op. cit.*, pp. 18, 28.

because it is planted late and has also the longest growing period²¹ among the spring-sown grains covered by this study.

The average frost-free period throughout the United States is presented in Chart 29. The frost-free period in individual years may obviously be substantially less than the average. The time available for the growth of crops declines rapidly from south to north. Within Minnesota, for example, the decline is from an average of approximately 150 to only 105 to 110 days. At Brandon, in southern Manitoba, the average frost-free period in 1909-28 was only 102 days, and in 1917, only 68 days passed from the last spring to the first fall frost.²²

In respect to length of frost-free period, the situation even in eastern Europe, where the period is much less than in western Europe, is considerably more favorable for crop production than in North America. Kharkov, Ukraine, located a little farther north than Brandon, Manitoba, has an average frost-free period of approximately 160 days, while in Orenburg near the border of Asia (approximately the same latitude) about 150 days are available. The frost-free period at Moscow, located at approximately the 54° parallel, is about 130 days. To find in western Russia a frost-free period as short as 100 days, it is necessary to go as far north as Leningrad, located on the 60° parallel.

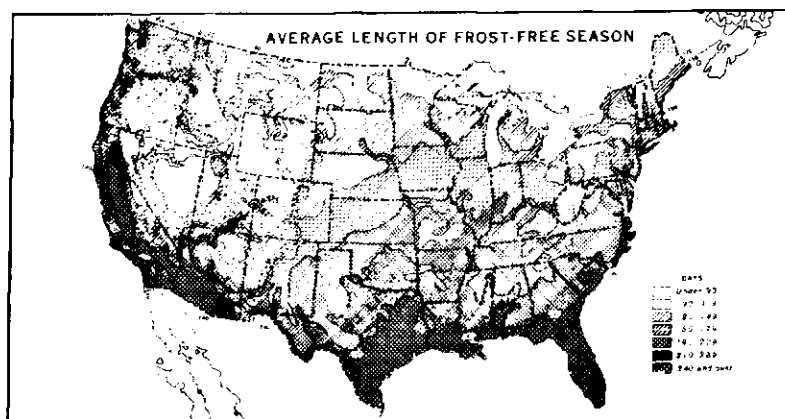
The growing period of the several crops varies considerably in different latitudes. Variations in the total growing period of winter grains are caused primarily by the different length of the dormant period. In the far north, almost a full year elapses between seeding to maturity. At the northernmost edge of winter-rye growing in Russia, year-old seed must ordinarily be used, since the seeding has to be completed before the grain of the current crop has been threshed.²³ The farther south in the Northern Hemisphere,

²¹ The expression "growing period" as used here covers the time from seeding to maturity and consequently includes the dormant period, if any, for fall-sown grains.

²² A. T. Elders and M. J. Tinline, *Corn Growing in Manitoba* (Canada Dept. Agr. Bull. 121, New Series, 1929), p. 4.

²³ N. I. Vavilov and others, "Crop Breeding in Connection with the Prospect of Agriculture in the USSR," *The Crops of the USSR* (already cited), pp. v-xv.

CHART 29



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the shorter is the period from seeding of fall-sown grains to their maturity. In regions where growth of fall or winter-sown grain continues through the winter, this period may be only half as long as in the far north, or even less. Moreover, the difference between winter and spring grain tends to disappear under such growing conditions. Some varieties are classed as intermediate, and grain of spring habit is frequently sown in the fall even where crops are dormant for a short period.²⁴

Sown in the fall, grain matures ahead of similar grain sown in the spring. Of the fall-sown grains, fall-sown barley is the first to be ready and wheat is last. Oats and rye occupy the intermediate positions.

The growing period of spring-sown grain changes in length in the direction opposite to that of winter grain. It declines from equator to poles, partly owing to the longer summer days in the north. Plants violently resist, however, the reduction of the growing period below certain minima; more-

²⁴ This practice is common with regard to barley and oats, but wheat of spring habit also is widely used for fall sowing. Practically all the durum wheat grown as a winter crop in North Africa and elsewhere is of spring habit. See C. L. Alsberg, "Durum Wheats and Their Utilization," *Wheat Studies*, April 1939, XV, 338.

over, the decrease in the number of days required to maturity within those limits is accompanied by a decline in yields (and frequently in the quality of the grain as well).

Of the grains here studied, spring barley requires the smallest time from seeding to maturity. The minimum is approximately 80 days.²⁵ Some 100 days is the minimum for spring wheat. Spring rye and spring oats occupy intermediate positions.²⁶ Considering that both Sixty-Day and Kherson oats originated in southwestern Russia, it is somewhat surprising to find that, according to Prjanischnikow,²⁷ oats there require 116 to 123 days from seeding to maturity and are slightly later than wheat. In cool, moist climates, spring oats seem quite regularly to have the longest growing period among small grains.

Among the spring grains, corn shows the greatest variability in growing period. Early varieties like the Italian Cinquantino are ripe in somewhat less than 100 days,²⁸ while varieties grown in the southern United States usually are not ripe before 180 days. Where the frost-free period permits the growth of corn varieties with a long growing period, early varieties usually give relatively low yields. This does not necessarily mean, however, that the yield of corn declines from south to north. The reverse is true; as is common with other plants, the best yields are obtained near the coldward limits. A decline of corn yields can be observed only in the northernmost regions of corn growing, too cold for varieties requiring 120 to 130 days to ripen. The minimum for varieties producing high yields seems to be 120 to 125 days for dent corn, and possibly a few days less for flint corn.

²⁵ Experiments in North Dakota indicate for different varieties 72 to 76 days from emergence to maturity. From seeding to emergence, 10 to 14 days elapse. T. E. Stoa, *Barley Production in North Dakota* (already cited), p. 37.

²⁶ The earlier varieties of oats—Sixty-Day and Kherson—require 80 days from emergence to maturity in North Dakota. T. E. Stoa and others, *Oats in North Dakota* (North Dakota Agr. Exp. Sta. Bull. 287, June 1936), pp. 10-11.

²⁷ D. N. Prjanischnikow, *Spezieller Pflanzenbau*, p. 226.

²⁸ All these names, Cinquantino, Carantino, Sixty-Day, and many more, convey erroneous impressions.

Experiments at Wooster, Ohio, showed the following relation between the average number of days from planting to silking and the average acre yields for groups of corn varieties on the average of 1930-34:²⁹

Number of varieties	Average number of days	Average yield in bushels
3	67.6	51.3
3	70.6	56.5
8	73.0	59.3
4	75.6	55.4
2	78.9	50.7

The increase in time from planting to silking from 67.6 to 73.0 days, i.e., by only 5.4 days, resulted in an additional yield equivalent to 16 per cent. Still later-maturing varieties produced less under conditions at Wooster owing to adverse fall weather.

The requirement of a relatively high soil temperature for germination necessitates planting corn a month or more later than spring wheat (p. 250). Since the growing period of corn is also longer by at least 10-15 days, the time of maturing even of early corn occurs 40-45 days later than that of wheat. In southern Minnesota, for example, corn planting begins about May 10. The earliest varieties cannot reach maturity before September 5 or 10, when the harvest of spring wheat is long past. In Kansas, approximately a quarter of a year separates the harvest of winter wheat from that of corn.

The effect of length of the frost-free period on the competition among grains is not limited to the possibility or impossibility of growing some specific grains, but it affects also the possibility of growing some specific combinations of grains. The combination corn-winter wheat, with or without hay as a third member of the rotation, is the most profitable under rather extended conditions. It greatly predominates in the Danubian countries and seems to play an important role in some Argentine regions (see p. 378). It is favored also in this country; but in a large part of the regions adapted

²⁹ *Handbook of Experiments in Agronomy* (already cited under Table 8), p. 32.

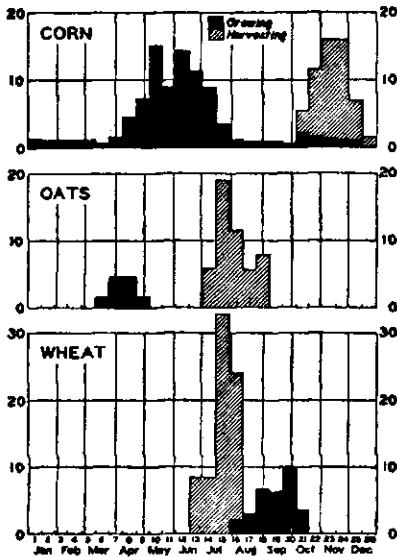


CHART 30.—SEASONAL DISTRIBUTION OF MAN LABOR ON SPECIFIED GRAINS IN EAST CENTRAL ILLINOIS*
(Hours per 10 acres)

* Reproduced in part from H. C. M. Case and others, *Organizing the Corn-Belt Farm for Profitable Production* (Illinois Agr. Exp. Sta. Bull. 239, June 1929), Fig. 15.

to both grains the sequence of corn-winter wheat causes considerable inconvenience owing to the shortness of the frost-free period, while some others have to abstain from it entirely for the same reason.

In northern Illinois, Indiana, Ohio, and similar locations, it is economically impossible to have winter wheat follow corn. Morison writes of conditions in northeastern Ohio: "Waiting for corn to mature and putting it into the silo or shock delayed wheat seeding too far beyond the optimum date."³⁰ In the central portions of those states some winter wheat is sown after corn reached maturity, but most of the corn is harvested at a time when next year's winter wheat has been in the ground for a longer time (see Chart 30 for the situation in central Illinois). In the west of the Corn Belt, winter wheat seldom follows corn as far south as Kansas.³¹ But winter wheat is grown after corn in Missouri and, to a large extent,

³⁰ F. L. Morison, *Variations in Crop Production Costs in Medina County, Ohio* (Ohio Agr. Exp. Sta. Bull. 453, June 1930), p. 30.

³¹ According to W. E. Grimes and others (*A Study of Farm Organization in Central Kansas*, U.S. Dept. Agr. Bull. 1296, Jan. 30, 1925, p. 36), most of the corn in central Kansas is husked in November or early December.

even in the southern portions of Illinois, Indiana, and further east.³²

HEAT REQUIREMENTS

The minimum heat requirement of crops is not a definite quantity, but changes with the amount of available heat and moisture. Grains produced with barely the minimum warmth available usually yield poorly, and ordinarily are not of good quality.

Corn occupies a special place among the grains covered in this study with regard also to its heat requirements, which greatly exceed the requirements of the other grains (but not sorghum). According to Krafft and Fruwirth³³ the total warmth required by different grains may be expressed as follows in degrees centigrade, the figures representing the sums of the average daily temperatures except of the days the temperature of which does not exceed $+6^{\circ}$ C.:

Spring barley	1700-2200
Spring rye	1750-2190
Spring wheat	1887-2275
Spring oats	2340-2730
Corn	2500-3000
Winter rye	2250-2950
Winter wheat	2563-3087

The data in the tabulation evidently are valid only for German conditions. Under extreme conditions spring wheat and the other small grains can do with as little as 1500° and even less. N. K. Sofoterow,³⁴ analyzing the data collected by the Allrussian Plant Institute, found the following quantities of warmth necessary for spring wheat at different degrees of northern latitude (in degrees centigrade):

³² Aside from the length of the frost-free period, the possibility of having winter wheat follow corn depends on the method of harvesting corn and seeding wheat, on the proportion of the land in corn, and on the labor supply. It will be necessary to return repeatedly to this important problem; see especially pp. 381-82.

³³ Guido Krafft (10th ed., revised by C. Fruwirth), *Die Pflanzenbaulehre (Lehrbuch der Landwirtschaft, Vol. II, Berlin, 1918)*, pp. 10, 26, 34, 43, 50.

³⁴ P. E. David, *Agricultural Meteorology* [translated title] (Moscow, 1936), pp. 217-18.

Latitude	From seeding to heading	From heading to ripening	Total
63-60°	824	720	1,544
60-57°	868	759	1,627
57-54°	900	858	1,758
54-51°	968	887	1,855
51-48°	985	930	1,915
48-45°	1,038	804	1,842

Experiments at Khibiny, which is located on the Cola peninsula at 67° 44' north latitude (beyond the arctic circle), showed that the earliest varieties of spring wheat matured in some years, while barley and oats matured rather regularly, although a total of only 1300° C. was available.³⁵

Corn, on the other hand, usually requires even more warmth than suggested by Krafft and Fruwirth. According to Seljaninow,³⁶ the minimum requirement of oats and spring wheat is 1600° C., and of the earliest types of corn 2300° C., but medium-early varieties of the type Leming require 3200° C., and the late varieties of the type Chicory even 4000° C. This large warmth requirement of corn greatly limits the extent of corn production, especially because a material fraction of the available warmth is lost owing to the late planting. The effect of the insufficiency of warmth on corn production runs through the whole range from merely reducing the yields without depriving corn of its strong competitive power, to such reduction of yields as to make corn unprofitable, and finally to physical impossibility of growing it. The first is strongly effective in North America, while the last two are particularly important in western Europe.

Wallace and Bressman³⁷ report on a Pennsylvania experiment in which “. . . it was found that during the twenty-two days preceding tasseling, those days with a mean

³⁵ *Ibid.*, p. 218. Grains produced at these peripheries of course yield very little and are of poor quality. Only under conditions of extreme poverty of the inhabitants does penetration of small grains into the northern regions coincide with the physical possibility of such penetration.

³⁶ G. T. Seljaninow, "The Specialization of Agricultural Regions on the Basis of Climate," in *The Crops of the USSR*, p. 7.

³⁷ H. A. Wallace and E. N. Bressman, *op. cit.*, p. 172.

temperature of less than 70° F. usually resulted in a growth of 3 to 3½ inches in twenty-four hours, whereas those days with a mean temperature of 75° or more resulted in a growth of 5 to 5½ inches in twenty-four hours.”

Mattice computed the yields from various weather factors in nine Corn Belt states in 1901–25. The computed yields coincided rather closely with the yields actually obtained. From his equations it is obvious that in the states of Minnesota, Indiana, and Ohio yields of corn are positively correlated with the amount of warmth.⁸⁸ Specifically, Mattice found the following correlations with yields:

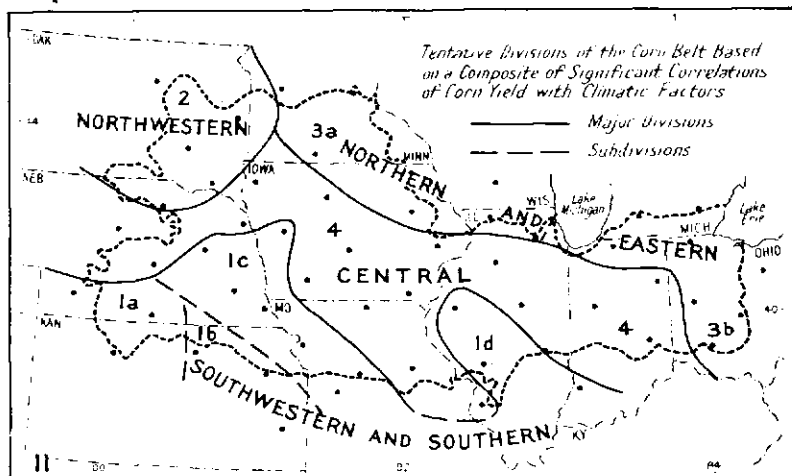
State	Correlation	Variables
Ohio	Positive	Mean temperature, June and September
		Mean maximum temperature, April and September
		Percentage of possible sunshine, June and July
Indiana	Positive	Percentage of possible sunshine, May
		Mean maximum temperature, September
Minnesota	Positive	Mean temperature, June
		Mean maximum temperature, August
		Percentage of possible sunshine, July
	Negative	Percentage of possible sunshine, April

Thus the percentage of possible sunshine in April in Minnesota was the only case of negative correlation between the yield of corn and the amount of warmth (a high percentage of possible sunshine tends to be accompanied by high temperature). But corn is not planted before May in that state. The high percentage of sunshine in April may have exerted a negative effect on yields because it probably was accompanied by dryness. For the whole state of Illinois, according to Mattice, warmth exerted a *negative* effect on yields. The result might have been different if only the northern half of the state had been considered.

Chart 31 shows one investigator's recent subdivision of the

⁸⁸ W. A. Mattice, "Weather and Corn Yields," *Monthly Weather Review*, March 1931, LIX, 105–12.

CHART 31*



* From J. K. Rose, "Corn Yield and Climate in the Corn Belt," *Geographical Review*, January 1936, XXVI, 98. Reproduced by courtesy of the *Geographical Review*, published by the American Geographical Society of New York. Rose's division is based almost exclusively on climate. Only area 4 is one "in which variations in climatic conditions do not seem to be critical for corn yields." Outside of it, one or several climatic factors do not satisfy this grain, requiring rather specific climatic conditions for realizing its full yielding power. The southwest of the area, for example, is too dry for this, while in the north the amount of warmth is insufficient. See the detailed description of the areas in Rose, *ibid.*, pp. 99-100.

Corn Belt. Of his area 3, which includes the northeastern portion of Iowa, northern Illinois and Indiana, the eastern portion of Ohio and the southern portions of Minnesota, Wisconsin, and Michigan, Rose states: "Area 3 is one in which early-season temperatures are critical. Corn in this area needs more heat during planting and the time of early growth."³⁹

There is a common belief that corn needs both warm days and warm nights, and that corn will not produce good yields in regions where the nights are cool though the days are warm. Experience in the Pacific and Mountain states seems to support this assumption. Cold nights are brought forward also as the explanation of the fact that corn does not do well in Chile.⁴⁰

³⁹ J. K. Rose, *op. cit.* (under Chart 31), p. 99.

⁴⁰ C. F. Jones, "Agricultural Regions of South America—Instalment III," *Economic Geography*, July 1928, IV, 271.

Yet Wallace and Bressman write:⁴¹ "Cool nights reduce the rapidity of growth previous to tasseling, but if the season is long there is no definite proof that cool nights (55 to 60 degrees at the low point of the night) reduce the yield." In support of this view, the situation in South Africa is cited, ". . . where corn growing has expanded at a phenomenal rate since 1900 . . ." and ". . . [where] the minimum temperature at night during the tasseling season averages only about 60 degrees, and in some sections it is as low as 55 degrees." It is important to add that the average yields obtained in South Africa are far lower than in any important corn-growing country of the world—less than a third of the average yield in Argentina—and that everybody in South Africa realizes that conditions there are not favorable for corn; indeed, programs are devised for shifts in agriculture which would eliminate exports of corn on a large scale. The present writer is inclined to regard the situation in South Africa as supporting the supposition that warm nights are important for successful corn growing.⁴²

In North America the total available warmth is not the principal factor in the northward penetration of corn, for the shortness of the frost-free period stops corn growing before the available amount of warmth has approached the minimum point. In all of western Europe and in a major part of central Europe, on the contrary, the frost-free period is much longer than the minimum required by corn, while the total available amount of warmth is definitely insufficient except in the south. Throughout that area, again excepting the south, temperatures are everything but those belonging to good corn weather. The springs, though free from late frosts, are cold, and corn would have to be sown very late. After sowing, it cannot make fast progress owing to insufficiency of warmth. At maturing time, when warm sunny weather is

⁴¹ H. A. Wallace and E. N. Bressman, *op. cit.*, p. 309.

⁴² Insufficient warmth at night of course is only one of the obstacles, possibly a minor one, to successful corn growing in British South Africa. See pp. 456-57.

needed, cold and rainy autumn weather prevails, though without killing frosts. Even in eastern Europe, the amount of warmth rather than the length of the frost-free period is the limiting temperature factor to northern penetration of corn.

HEAT RESISTANCE

As stated above, the varieties grown at the extreme edges of the coldward penetration of each grain crop yield but poorly. However, outside of the regions where the amount of available warmth just equals or only slightly exceeds the minimum requirements, yields show a distinct tendency to decline from pole to equator. One of the most important causes seems to be excess of heat. Excessive heat is a much more important factor limiting the geographical spread of small grains than are minimum requirements of those grains for warmth; and the limitations to corn growing are also very significant.

The expression heat resistance is used in two senses. One plant may really exceed another in ability to resist heat, but it may also yield relatively better than the other simply because its growing period falls into a cooler part of the year. It is in some cases extremely difficult to segregate ability to withstand heat from ability to yield better by avoiding the hottest spells. Another difficulty encountered in the analysis of the effect of excessive heat is that the ability to withstand *dry hot air* is very difficult to differentiate from the ability to withstand insufficiency of moisture in the soil. These two complications make our conclusions in part uncertain. It is in any case better to discuss separately the effects of moist heat and of dry heat on yields.

Moist heat.—Corn seems to surpass all spring-sown small grains in ability to withstand high temperature of the air in the presence of sufficient moisture. This is not surprising for a plant which supposedly originated in the tropics. But it is somewhat surprising to find that spring barley is inferior, or at least is not superior, to oats in this regard. Oats and rye rightfully enjoy the reputation of being the grains of cool climates. Yet oats, which possess a considerable ability to adapt

themselves to most different growing conditions, show also a substantial ability to withstand a fair amount of moist heat. Spring-sown wheat and spring-sown rye are not grown in humid hot areas. This makes it difficult to rank them in regard to ability to withstand moist heat, but also not very important to rank them.

The greater ability of corn to withstand moist heat as compared with oats can be demonstrated by the yields of these grains in Minnesota and Iowa. Northern Minnesota has too short a frost-free period and also insufficient heat for the best yields of corn. Otherwise the selected region is well suited for the purposes of comparison. The following tabulation shows the yields of oats expressed in percentages of corn yields in the states named, by crop-reporting districts which are arranged in geographical order from west to east and from north to south:⁴³

District	Western	Central	Eastern
Minnesota			
Northern	68.3	74.9	81.5
Central	65.8	62.9	70.0
Southern	67.1	60.9	58.1
Iowa			
Northern	54.6	57.3	51.7
Central	45.7	49.4	49.5
Southern	43.7	45.7	46.0

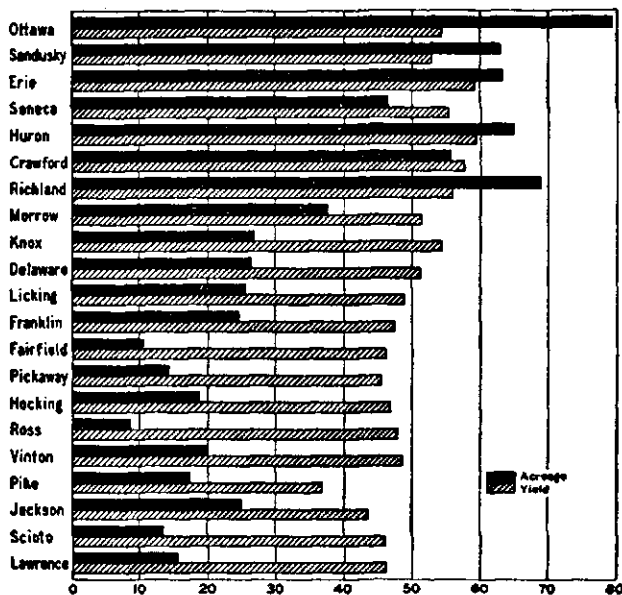
According to these data, corn persistently improves its position from north to south as compared to oats. While in central Minnesota oats produce approximately two-thirds of the corn yield, the yield of oats in southern Iowa and northern Missouri averages only about 45 per cent of that of corn. The differences in yields of corn and oats are clearly reflected in acreages (compare Chart 38, p. 271 with Chart 35, p. 267).

Chart 32, which presents a cross section through the central part of Ohio from north to south, in general using two counties in each latitude, reveals a similar picture. In the

⁴³ For details on years used in this computation, see Appendix Note B.

CHART 32.—ACREAGE AND YIELD RATIOS BETWEEN OATS AND CORN, IN OHIO COUNTIES FROM NORTH TO SOUTH*

(Oats acreage and yield in per cent of corn acreage and yield)



* Data from J. I. Falconer, *Twenty Years of Ohio Agriculture, 1910-30* (Ohio Agr. Exp. Sta. Bull. 526, July 1933). Acreages of 1929, average yields of 1920-29.

northern portion of the state approximately as many bushels of oats of 32 pounds as bushels of corn of 56 pounds are produced per acre (equivalent to 57:100 on a weight basis). In some northern counties the yield of oats in bushels of 32 pounds even somewhat exceeds that of corn in bushels of 56 pounds. At this ratio between yields, the acreage in oats was more than half of that of corn. In southern Ohio, corn was far ahead of oats in yields even in bushels of unequal weight. In the southernmost county, Lawrence, oats produced only 45 per cent as much as corn on a poundage basis (some southern counties showed ratios still less favorable to oats), and the area in oats did not exceed 15 per cent of that of corn. The improvement of the ratio between the yield of corn and of oats in favor of corn from north to south in Ohio may be due

partly to the shortness of the frost-free period for corn in the far north of the state, and to soil conditions. Yet the greater susceptibility of oats to heat is undoubtedly a large factor in the relative decline of oat yields as compared to those of corn from north to south in Ohio and adjacent states.⁴⁴

Corn has to withstand the heat of the whole summer while oats escape part of it. Hence, the decline of yields of oats relative to those of corn from north to south in the states mentioned can be taken to indicate that corn is able to withstand moist heat much better than oats.

In one of Harlan's barley studies,⁴⁵ an outline map of the United States indicates the area in which the climate is relatively more favorable for barley than oats. In that area well-drained soils not sandy in character produce more pounds of barley than of oats to the acre. Within the moister part of the United States, the boundary of this area extends from Massachusetts past the southern extremities of Lake Erie and Lake Michigan, and cuts the state of Iowa about in half. In all the vast territory south of that line, according to Harlan, barley is not expected to outyield oats even on soils suited to the former. Since spring barley matures ahead of spring oats, the only reasonable explanation is that barley suffers at least as much from hot moist temperatures as oats. Lodging is a problem, but there is also large damage from diseases—especially for barley following corn—and bugs which reduce yields and occasionally can make the barley unusable for any purpose.⁴⁶

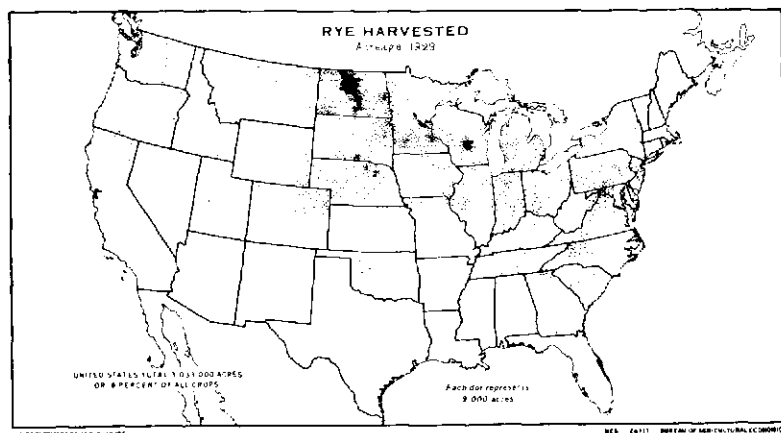
In ability to withstand moist heat, winter rye seems to be the least resistant winter grain. So little rye is grown in this

⁴⁴ The heavy decline in the ratio of oats acreage to corn acreage in the southern portion of the state is brought about primarily by the lesser necessity of including oats in the rotation as compared with the situation in the northern portion of the state. But low yields may be a contributing factor. The same is true of the distribution of acreage in Minnesota and Iowa discussed in the preceding paragraph, and of that in the northern Corn Belt generally.

⁴⁵ H. V. Harlan, *Barley: Culture, Uses, and Varieties* (U.S. Dept. Agr. Farmers' Bull. 1464, October 1925), p. 5.

⁴⁶ L. C. Burnett and C. S. Reddy, *Barley in Iowa* (Iowa Agr. Exp. Sta. Bull. 367, October 1937).

CHART 33



country (Chart 33) except in restricted areas that official data on rye yields cannot be relied upon in this connection. This is particularly because, outside of the regions of concentrated rye production, rye sowings are mostly used for fall and spring pasturing, only what is not needed for the livestock being harvested for grain. Heavily pastured fields yield little grain. Among other states, the practice of pasturing seems to be extensive both in Iowa and Missouri. Yet, on the average of 1923-32, rye in Missouri yielded 40 per cent less than in Iowa, while wheat yielded only 29 per cent less.⁴⁷ Since winter wheat ripens later than winter rye, we again have evidence of real relative ability of wheat to withstand moist heat, rather than simply a property of escaping it by early maturity. Harlan's map evidently pertains also to oats and barley sown in the fall, and must be taken as indicating that oats are at least as good as barley with reference to resistance to moist heat whether the sowing is done in the spring or in the fall. This indication is supported by the fact that in moister regions of the United States which are sufficiently warm to grow winter oats, the small acreage in this grain is several times larger than the acreage devoted to winter barley.

⁴⁷ The fact that the soil of Missouri is not so good as that of Iowa should have depressed wheat yields more than rye yields.

As to whether fall-sown wheat or fall-sown oats can better withstand moist heat, lack of information precludes definite statements; but wheat seems to be superior to oats.

Dry heat.—As stated, the ability of grains to withstand dry, hot air is difficult to differentiate from their ability to withstand dryness of the soil. On soils suitable for barley, barley yields materially more than oats in dry heat and with scanty supply of soil moisture. With regard to spring-sown grains this is clearly apparent from Table 10. In no crop-

TABLE 10.—YIELDS OF BARLEY IN PERCENTAGES OF OATS YIELDS IN SPECIFIED STATES BY CROP-REPORTING DISTRICTS*

		<i>(Oats yields = 100)</i>		
State	District	Western	Central	Eastern
North Dakota . . .	{ Northern	122	116	117
	{ Central	125	123	121
	{ Southern	128	122	115
South Dakota . . .	{ Northern	110	104	101
	{ Central	114	108	112
	{ Southern	116	121	126
Nebraska	{ Northern	} 132 }	119	140
	{ Central		141	142
	{ Southern		122	126
Kansas	{ Northern	148	107	122
	{ Central	138	111	127
	{ Southern	145	125	117

* Official data. For South Dakota, averages of 1924-35; on years for other states, see Appendix Note B.

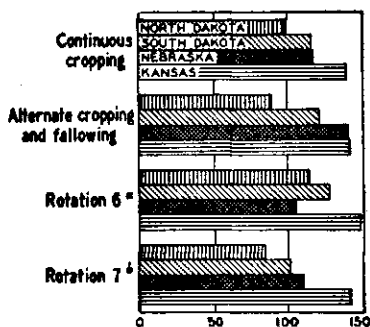
reporting district did the yield of oats reach that of barley in the four states covered, not even in their eastern portions, relatively well supplied with moisture. Moreover, the yield of barley in terms of oat yield tends to be higher in the more southern and hotter states than in the more northern and cooler ones. In western Kansas, for example, barley yields almost 45 per cent more than oats, while in western North Dakota the advantage in favor of barley is 25 per cent. The superiority of barley over oats in eastern Kansas also is slightly greater than in eastern North Dakota. But the data

CHART 34.—BARLEY YIELDS IN PERCENTAGES OF OATS YIELDS AT EXPERIMENT FIELDS IN SPECIFIED STATES OF THE GREAT PLAINS*

* Basic data from E. C. Chilcott, *The Relations between Crop Yields and Precipitation in the Great Plains Area* (U.S. Dept. Agr. Misc. Circ. 81, February 1927), and its *Supplement 1.—Crop Rotations and Tillage Methods* (October 1931), brought up to date in U.S. Department of Agriculture, Bureau of Plant Industry, Division of Dry Land Agriculture; thanks are due to J. S. Cole, Senior Agronomist in that bureau, for supplying the data.

* The sequence of crops is: barley on disked corn land followed by oats and corn, both on early spring plowing.

^b The sequence of crops is: barley, oats, and corn, all on spring plowing.



are by no means in full agreement, and afford proof of the ability of oats, the cool-weather crop, to adjust even to dry heat to some extent.

Spring barley nevertheless may be considered to have a definite advantage over spring oats in dry hot air. This generalization is supported by a comparison of average yields of oats and barley obtained at experiment stations in the northern Great Plains (Chart 34).⁴⁸ In rotation 7, which favors oats (oats following corn),⁴⁹ oats outyielded barley only in North Dakota. In continuous cropping, and alternate cropping and fallow—the two crop sequences in which neither grain was favored—the yield of barley was only once (again in North Dakota) less than that of oats. Moreover, with a few exceptions, the tendency of barley yields to improve relative to oat yields from north to south is both persistent and strong. In Kansas, all rotations show barley not less than 40 per cent ahead of oats in yield.

Comparison of Charts 35 and 36, despite the great difference in the significance of individual dots in the two charts, shows clearly the tendency of barley to gain over oats as we move southward in the Great Plains. The relatively great

⁴⁸ In the four states shown in the chart, there are 10 stations which are located within the Northern Great Plains: 4 in North Dakota, and 2 each in South Dakota, Nebraska, and Kansas. Garden City, Kansas, is taken as located in the southern Great Plains.

⁴⁹ Small grains commonly yield better after corn than after small grains.

acreage of barley in northwestern Kansas and adjacent portions of Colorado and Nebraska is particularly in evidence.

Spring barley retains its advantage over spring oats in yielding capacity in the Prairie Provinces of Canada also, but its superiority is less than farther south, probably owing to the cooler climate in Canada.

CHART 35

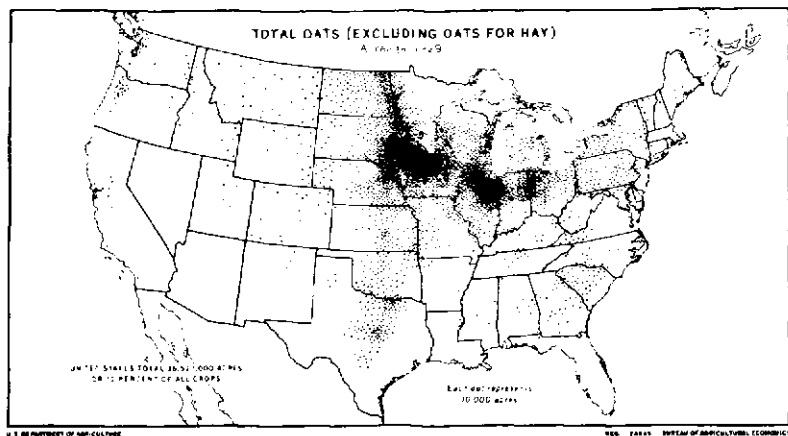
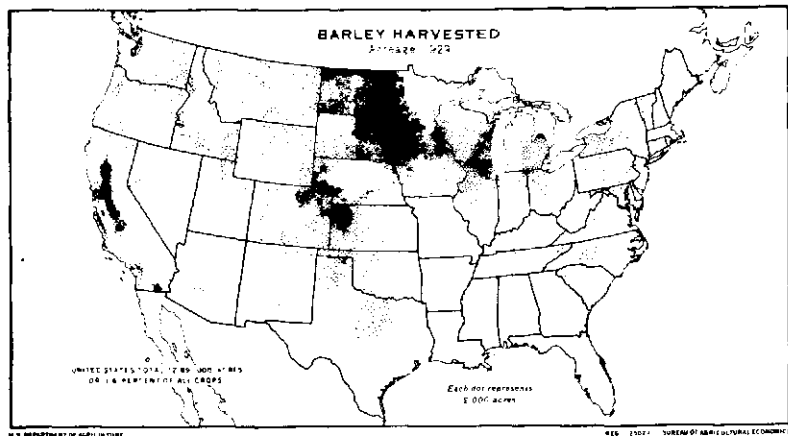


CHART 36*



* Attention is drawn to the fact that in Chart 35 each dot represents five times as many acres as in Chart 36. Barley acreage excludes barley harvested for hay.

The situation in the south of European Russia seems to be almost as favorable to spring barley as compared with spring oats as in the Great Plains. This advantage, however, is not sustained in the east of the Volga and in Siberia. For this phenomenon the Russian authority Prjanischnikow⁵⁰ suggests the explanation that oats are inferior to barley only in withstanding dryness of the soil and not in withstanding dry air. Another possible explanation is that the agricultural regions east of the Volga are located much more to the north than those in southernmost European Russia. In favor of this explanation is the analogy to the situation in Kansas on the one hand and to that of the Prairie Provinces of Canada on the other. But the final word on the adaptability of barley to eastern Russia may not yet have been said.

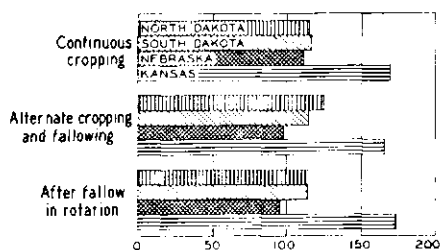
The absorption of nutrients by barley is concentrated in the early period of growth (pp. 228, 231). This "earliness," more than earliness in ripening (barley in dry hot climates ripens only slightly ahead of oats, of which the growing period is shortened by dry heat more than that of any other small grain), is likely to be important in making spring barley yield better than spring oats in regions with hot summers.

Talanow and Kusmin⁵¹ infer that spring barley is more resistant to dry heat spells than is spring wheat. This finding is in agreement with experience in the United States. But what is the effect of dry heat on the relative yields of spring wheat and spring oats? Chart 37 shows that in the Dakotas spring oats display merely an approximately normal superiority in yield over spring wheat, while in Nebraska the yields of oats seem to be affected by the increasing heat even more than those of spring wheat. In Kansas, it is true, spring oats are far more superior. Moreover, at Garden City, the driest of the three Kansas stations located in the Great Plains, which is not included in the chart, spring oats yielded almost twice

⁵⁰ D. H. Prjanischnikow, *The Field Crops*, p. 178.

⁵¹ W. W. Talanow and W. P. Kusmin, "The Requirements of Individual Crops as to Growing Conditions and the Possibility of Their Expansion and Shifts to Certain Regions of the USSR," *The Crops of the USSR*, p. 70.

CHART 37.—SPRING-OATS YIELDS IN PERCENTAGES OF SPRING-WHEAT YIELDS AT EXPERIMENT FIELDS IN SPECIFIED STATES OF THE GREAT PLAINS*



* See note to Chart 34 for sources. The yields designated "after fallow in rotation" are from rotation 5 (wheat on fallow; oats on early fall plowing) for wheat, and from rotation 8 (oats on fallow; wheat on early spring plowing) for oats.

as much as spring wheat in the period covered by the chart. But Dr. Bayles⁵² explains the poor showing of spring wheat at the Kansas stations by the use of unadapted varieties. With the Kansas data dismissed as inconclusive, the behavior of spring oats and spring wheat becomes rather similar. Moreover, it is not improbable that spring oats suffer more from the dry heat; but this is offset—fully or to a large extent—by their earliness and the lesser amount of moisture needed per unit of grain.

Corn withstands dry heat better than any of the four small grains considered in this study, but nevertheless also suffers badly from it, being particularly susceptible during tasseling time. According to Rose, while corn in northeastern Iowa is unfavorably affected by low temperatures, in southwestern Iowa the opposite is observed.⁵³ The excess of heat is still more harmful farther to the southwest. The only two variables used by Mattice in his equation for Missouri are mean maximum temperatures in July and in August, both as negative factors.⁵⁴ Baker⁵⁵ writes: ". . . the hot belt extending

⁵² B. B. Bayles, Agronomist in the Bureau of Plant Industry, U.S. Department of Agriculture.

⁵³ J. K. Rose, *op. cit.*, p. 92.

⁵⁴ W. A. Mattice, *op. cit.*, p. 107.

⁵⁵ O. E. Baker, "Agricultural Regions of North America: Part X—The Grazing and Irrigated Crops Region (continued)," *Economic Geography*, October 1932 VIII, 353.

CHART 38

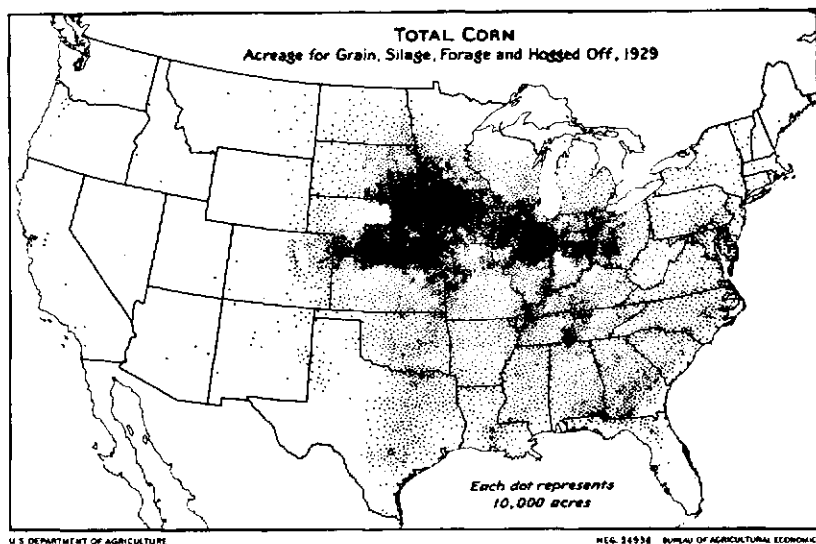
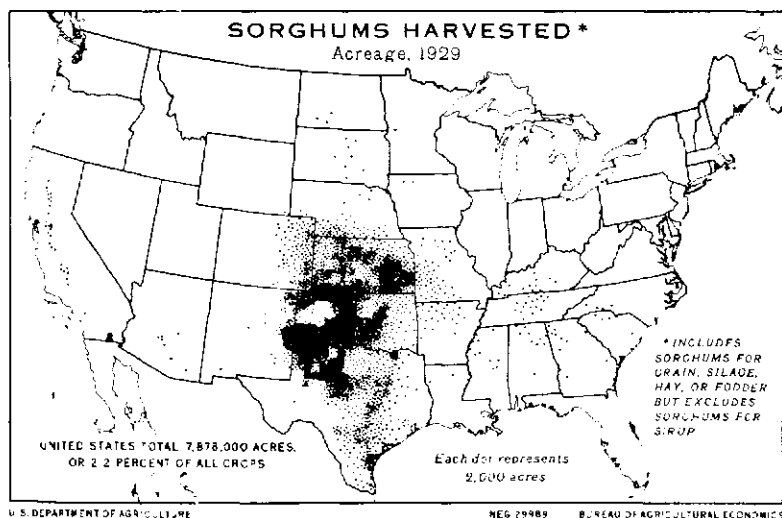


CHART 39*



* Attention is drawn to the fact that in Chart 38 each dot represents five times as many acres as in Chart 39.

up the Rio Grande from the east and up the lower Colorado and Gila Rivers from the west is almost devoid of corn. Under conditions of great heat and dryness, the corn ears do not fill well—apparently the dryness of the air depletes the vitality of the pollen.”

While spring-sown oats are not a competitor of corn where dry heat has to be withstood, and spring-sown barley also is not very dangerous, corn succumbs to the competition of sorghums under these conditions, as soon as the high temperature requirements of sorghum are met.⁵⁶ A comparison of Charts 38 and 39 demonstrates this.⁵⁷ In southwestern Kansas, western Oklahoma, and northwestern Texas, corn almost disappears, sorghum taking its place for both grain and fodder. The yields obtained in that region show the hopeless position of corn. As an example, the yields of corn and sorghum in continuous cropping at Hays in western Kansas and at Woodward in northwestern Oklahoma are presented below:⁵⁸

Station	Grain (bushels)		Grain and stover (pounds)	
	Corn	Sorghum	Corn	Sorghum
Hays, Kansas	5.6	14.1-14.4	2,777	4,906
Woodward, Oklahoma	7.0	16.7-21.4	2,101	4,937-7,289

Let us now turn to the effect of dry heat on the competition among fall-sown grains. Fall-sown barley commands over fall-sown wheat approximately as great an advantage in dry heat as is observed for the same grains when spring-sown. In a series of experiments conducted at different points in California, fall-sown barley outyielded fall-sown wheat by 39 per cent.⁵⁹ Professor R. L. Adams of the University of California

⁵⁶ Sorghum, which has an even higher minimum germinating temperature than corn and is therefore sown considerably later than corn, needs nevertheless plenty of warmth to mature.

⁵⁷ As in the case of Charts 35 and 36, there are five times as many acres per dot in the chart for corn as there are acres in the chart for sorghums; this should be borne in mind in comparing the charts.

⁵⁸ E. C. Chilcott, *op. cit.*, *Supplement 1*, pp. 61, 134-37. For details on growing grain sorghum in the southern Great Plains, see J. H. Martin and others, *Growing and Feeding Grain Sorghums* (U.S. Dept. Agr. Farmers' Bull. 1764, December 1936).

⁵⁹ Information kindly supplied by G. A. Wiebe, Agronomist in Barley Investigations, Bureau of Plant Industry, U.S. Department of Agriculture.

operates with a "usual" per-acre yield in dry farming of 1,000 pounds of barley and 700 pounds of wheat.⁶⁰

Fall-sown barley proves considerably more superior to fall-sown oats in dry heat than is true of spring-sown grains. California oat acreage, for example, is only about one-tenth of that of barley. Some of it is grown near the ocean or irrigated. The bulk is produced in the interior valleys without irrigation, but practically all of it on hills lying within the area invaded by moist oceanic air. A substantial portion of the small oat acreage, moreover, is cut and fed unthreshed or made into hay, in which case the disadvantage of oats in yield relative to that of barley is materially less.

In the Californian experiments cited, fall-sown oats yielded only 58 per cent as much grain as barley. In Tunis and other French colonies in northern Africa some oats are grown in the better-watered parts, but none can be found in the driest sections. The situation seems to be similarly unfavorable to oats in the other warm regions with a Mediterranean climate such as Spain and Asia Minor. Only the Australian regions with Mediterranean climate are exceptional. There, as well as in the remaining Australian grain regions, oats rather than barley are the crop which has been able to attain some importance in addition to wheat as the dominant crop.

The superiority of barley—both fall-sown and spring-sown—over similarly grown oats in dry heat would be impossible of realization, unless barley could do with less moisture than oats. But that ability to withstand heat is also important is evidenced not only by the fact that the superiority of barley tends to rise with increase in temperatures but also by the fact that barley retains a substantial portion of its superiority in dry regions, if ample moisture is provided by irrigation.

The relative position of spring wheat and spring oats in

⁶⁰ The yield of barley in the whole state (1923-32) was higher than that of wheat by only 18 per cent; but there is no doubt that on the same lands barley makes a much better showing, for barley on the average is grown on poorer land (especially on much more weedy land) and also in drier sections. The proportion of irrigated wheat to total wheat acreage, moreover, is larger than in the case of barley.

dry heat seems not to be repeated for the same grains when sown in the fall. In the Great Plains heat seems to do about as much harm to spring wheat as to spring oats and oats continue to be the heavier yielder. In the California experiments, however, fall-sown oats were outyielded by fall-sown wheat by 24 per cent. Insufficient attention of breeders to oats, which could not compete with barley even with substantially higher yields, might have contributed to their failure. But the fact seems to be rather firmly established that yields of fall-sown oats are depressed in dry-heat conditions more than yields of fall-sown wheat.⁶¹

There is little doubt that the ability of winter wheat to withstand hot spells so greatly exceeds that of winter rye that winter wheat under conditions of dry hot summers is at an advantage in spite of the earlier maturity of rye. At Woodward, Oklahoma, winter wheat and winter rye yielded as follows, in centals per acre, on the average in 1919-26:⁶²

Crop sequence	Winter wheat	Winter rye
Continuous cropping	10.4	7.4
Alternate fallow	14.0	8.8

The difference in favor of wheat was equivalent to 41 to 59 per cent. Farther north, at Lincoln, Nebraska, one variety of winter rye (Rosen) yielded only 2 per cent less than the standard variety of winter wheat (Nebraska No. 60).⁶³

The preceding analysis has covered the effect of excessive heat on the yields of spring and winter grains separately. The competition, however, is frequently between representatives of both types of grain. This brings us back to the problem of the advantage of winter-hardiness. This advantage varies greatly with temperatures (and moisture). The difference in

⁶¹ Irrigation apparently does not improve the competitive power of fall-sown oats with fall-sown wheat under dry-heat conditions. As to spring wheat and spring oats, evidence indicates that the response of spring wheat to irrigation is stronger than that of spring oats even in terms of quantities of grain; but the evidence can hardly be considered conclusive.

⁶² E. C. Chilcott, *op. cit.*, *Supplement 1*, pp. 134-35.

⁶³ Data for 1919-23; see T. A. Kiesselbach, *Winter Wheat Investigations* (Nebraska Agr. Exp. Sta. Research Bull. 31, November 1925), p. 142.

yield is probably within perhaps 15 per cent in favor of winter grain where the supply of moisture is sufficient and summer temperatures are moderate. Even a difference of this size may be decisive. Moreover, the absence of one of the above requirements increases the superiority of winter grain. Urbana, Illinois, and especially DeKalb, Illinois, are not places which can be considered extremely hot. Yet winter wheat outyielded spring wheat in DeKalb by 29 per cent, while in Urbana, some 100 miles to the south, the yield of winter wheat was larger by no less than 58 per cent.⁶⁴ At Hays, in west central Kansas, where it is both hot and dry, winter wheat in continuous cropping yielded 15.3 bushels on early fall plowing as against 6.4 bushels of spring wheat on fall plowing in 1907-37. The figures for alternate cropping and fallow were 23.7 and 9.8 bushels. The use of better adapted varieties of spring wheat at Hays would not have changed this relationship fundamentally.

The farther to the south, the greater in general is the summer heat but the earlier does the fall-sown grain mature. By being sown in the fall, small grains, the grains of moderate climates, can thus penetrate into regions which may be too hot even for corn, the grain of hot climates. In parts of western Oklahoma and western Texas where the dry heat is excessive for corn, winter wheat which matures by the end of May or early in June can still be produced to advantage. At Lawton, Oklahoma, corn in continuous cropping yielded only 11 per cent more than similarly grown winter wheat, while farther north, at North Platte, Nebraska, the yield of continuous corn was 66 per cent higher than that of continuous winter wheat.

The great significance of the escape into fall sowing, for wheat in its competition with corn, is clearly evident where such escape is impossible. In South Dakota and parts of Nebraska, the climate is too severe for winter wheat but rather

⁶⁴ Averages for 1916-25 at Urbana, and for 1915-19 and 1921-25 at DeKalb. R. W. Stark, *Spring Wheat Production in Illinois* (Illinois Agr. Exp. Sta. Bull. 287, March 1927), p. 339. Experiments with crops of little significance in a certain area all too frequently are impaired by the use of unadapted varieties. This may be true of spring wheat in Iowa.

hot for spring wheat. The competitive position of corn against wheat under these conditions becomes approximately as favorable as it is in the heart of the Corn Belt, in spite of the insufficiency of moisture for the best corn yields. Wheat yields there seem to be affected by heat as much as corn yields are affected by insufficiency of moisture (Chart 44, p. 303, clearly demonstrates the break of corn between the spring-wheat area in the north and the winter-wheat area in the south).⁶⁵

The ability of winter wheat to compete with spring barley and spring oats is also considerably enhanced under conditions of dry hot summers, in spite of the fact that they mature ahead of the worst heats.⁶⁶

Though rye is the grain which most vigorously objects to heat, it also has some advantage from the unfavorable effect of heat on the yields of spring grain in those regions with relatively hot climate in which rye is the only grain that can be sown in the fall. The relative strength of rye in the north of the Great Plains can be traced partly to this fact. The same is true of that portion of the Russian chernozem zone which is unadapted to winter wheat.

RECAPITULATION

In various combinations the individual temperature factors (winter-hardiness, minimum germination temperature, length of growing period, heat requirement, and heat resistance) produce such extremely divergent situations with regard to the competition among grains that a recapitulation seems useful. The Great Plains of the United States and Canada, and western Europe represent the two extremes, while eastern North America and eastern Europe occupy intermediate positions. But it seems advantageous to start with eastern Europe, owing to the availability of the data presented in Chart 22 (p. 217).

Chart 22 shows that in European Russia barley penetrates

⁶⁵ A large proportion of soils in that area, it is true, is unadapted to wheat; but the competition of corn seems to be strong even on soils suitable for wheat.

⁶⁶ See, for example, the data for the southernmost governments of Russia, p. 300.

farther north than any other grain. It is even grown beyond the arctic circle, but total production in the arctic regions is negligible. Spring rye is the grain that is added next as one moves southwards. The regions of spring barley—spring rye also are unimportant as grain producers. South of these regions oats and then wheat enter in their spring-sown forms, but also winter rye, the first fall-sown grain. In the conditions of eastern and east central Europe, the point where the growth of winter rye and spring oats becomes possible is of greatest importance, because over vast areas southward the soil is mostly unadapted to either barley or wheat. The possibility of growing those two grains means the possibility of large grain production.

As in the movement southward the chernozem is reached, the situation displays a great divergence between western Russia and adjacent regions from the west on the one hand, and from eastern Russia on the other hand. In the first group the competing crops are winter wheat, winter rye, spring barley, and spring oats, supplemented soon by corn. In the southernmost portion of those regions the early-maturing barley acquires a relatively strong position because spring oats suffer badly from heat, while moisture scarcity greatly hampers the growing of corn. In the chernozem zone of eastern Russia, however, the situation remains over a long distance the same as farther north, so far as concerns crops that are not excluded by temperature conditions. Winter rye, spring wheat, spring oats, and spring barley are the only grains which can be grown. Spring barley, a very strong competitor of oats in southwestern and south central Russia, weakens eastward for reasons not entirely clear to the writer. Corn growing does not become possible in eastern Russia well south of the northern border of the chernozem, but it penetrates considerably farther north than winter wheat, which is limited to North Caucasia.

The regions climatically adapted only to spring barley, or to spring barley and spring rye, remain largely unused in

North America, mainly because the small yields of cheap grains obtainable can assure only a miserable income to the grower. Otherwise the situation in the north of the Great Plains is similar to that in Siberia.

The most important borderline in western Canada as in Siberia is that which delineates the possibility of growing spring wheat.⁸⁷ The great event of the second decade of this century—not only for Canada but for the world grain market at large—was the introduction of the spring-wheat variety Marquis; this required 7 to 10 days less to mature than Red Fife, the variety commonly used before.⁸⁸ Marquis and still earlier varieties, introduced later, moved the Canadian wheat belt several hundred miles northward.⁸⁹ The lowering of the competitive position of spring oats relative to that of spring barley in the movement southward is as marked in the Great Plains as in western and central Russia.

As in eastern Russia, in the Great Plains and in the area immediately adjacent to the east, corn enters the battlefield much farther north than winter wheat. The area adapted to corn but unadapted to winter wheat comprises in the main the Dakotas, Minnesota, and parts of Nebraska, Montana, and Iowa. In the similar Russian area, scarcity of moisture prevents corn from getting much advantage from the weaker position of wheat. A large portion of such area in the United States, however, is much better supplied with moisture. Corn would be strong even if winter wheat could be grown without much loss from winterkilling, and the weaker position of wheat

⁸⁷ According to O. E. Baker ("Agricultural Regions of North America: Part VI—The Spring Wheat Region," already cited, p. 409), the northern limit is at an average summer (June, July, and August) temperature of 57° F.; wheat production on a large scale stops at 59° F.

⁸⁸ Canadian farmers sowed Marquis for the first time in the spring of 1909. A. H. R. Buller, *Essays on Wheat* (New York, 1919), p. 158.

⁸⁹ The problem of finding a suitable wheat for the northernmost region was also important in Siberia, but evidently not so acute as in western Canada. The principal reason for the difference probably was that for Canada the problem was to develop early-maturing varieties without sacrificing the quality of Canadian wheat. Siberia, however, has long produced wheat only for unexact local needs. Hence production became possible in spite of the fact that varieties adapted to the climate were very poor in quality. Some Siberian wheats are strongly discriminated against in European Russia, and probably in Siberia as well.

makes it even stronger. Where, in the Great Plains proper, winter wheat becomes fairly safe, the competition of corn is already weakened by dry heat.

The principal feature of the regions east of the Great Plains is that winter wheat penetrates approximately as far north as corn and that as one moves south oats gain rather than barley. Winter barley and winter oats can be grown over the vast expanse of southeastern United States, but this is an area where no small grain is important.

The situation in western Europe is peculiar in that winter wheat can be grown almost everywhere, while corn growing is confined by temperature to the southern regions. Even winter barley penetrates materially farther north than corn.

The Pacific states resemble western Europe in that not only winter wheat but also winter barley and winter oats can be grown over wider areas where corn growing is difficult.

The Australian and Argentine grain belts are among those where climate permits all small grains to be grown as fall-sown or winter-sown crops.

The geographical limitations upon grain growing, as sketched above, pertain to land located at sea level or moderate elevations. Increase in elevation is equivalent to a location farther from the equator. According to Hopkins, 400 feet of altitude are equivalent to approximately 1° of latitude.⁷⁰ In central Germany the climate is too severe for winter wheat at an elevation of only 1,500 feet and in the northern Alps even at only 1,000 feet. But in Peru barley, which is grown nearer to the sky than any other grain,⁷¹ reaches an elevation of 14,000 feet; at 11,000 feet corn is grown, although the important corn areas are below 8,000 feet.⁷² The situation is similar in the Himalayas⁷³ and other high mountains.

⁷⁰ A. D. Hopkins, "Periodical Events and Natural Laws as Guides to Agricultural Research and Practice," *Monthly Weather Review*, Supplement 9, 1918, p. 7.

⁷¹ Quinoa, a small-grain cereal, excels even barley, but its total production in that country probably does not exceed 2,000,000 pounds.

⁷² H. P. Milstead, "Distribution of Crops in Peru," *Economic Geography*, January 1928, IV, 99-101.

⁷³ Samuel Van Valkenburg, "Agricultural Regions of Asia: Part IV—India," *Economic Geography*, April 1933, IX, 135.

CHAPTER XII

MOISTURE

CLASSIFICATION OF REGIONS

As with temperatures, there are extreme variations in the moisture conditions under which grains are grown. (Annual precipitation in the world is shown in the upper section of Chart 40, p. 292.) Much grain is produced in semiarid regions, where crops only exceptionally have the moisture supply under which they develop best and where real droughts often occur. These regions even tend to be devoted exclusively to grain, so far as arable agriculture is practiced there at all. But grain is produced also in humid areas where it usually receives more moisture than can do it good. According to Bennett and Farnsworth, more than one-quarter of the world wheat area is in semiarid regions and more than 15 per cent in humid regions.¹ The predominant portion of world grain production is concentrated, it is true, in subhumid areas; but these are far from uniform. They include areas where the best moisture conditions for the development of grains prevail, as well as areas where insufficiency of moisture is the principal factor limiting yields. Regions well supplied with moisture, such as the German province of Mecklenburg on the one hand, and on the other hand practically all of European Russia, including such dry regions as the Crimea and adjacent portions of the mainland, are regarded as subhumid.

The subdivision of climates into semiarid, subhumid, and humid as used in the preceding paragraph² is designed for

¹M. K. Bennett and H. C. Farnsworth, "World Wheat Acreage, Yields, and Climates," *Wheat Studies*, March 1937, XIII, 279.

²That of C. W. Thornthwaite in "The Climates of the Earth," *Geographical Review*, July 1933, XXIII, 433-40. Thornthwaite's system was also used by Bennett and Farnsworth in the study cited. Realizing the wide range of moisture conditions found in his group of subhumid areas, Thornthwaite subdivides subhumid regions into four sub-groups: those with precipitation sufficient in all seasons, those with rainfall deficient in summer, those with precipitation deficient in winter, and those with precipitation deficient in all seasons.

general requirements, and is not quite adequate for the analysis of conditions in grain growing. A subdivision into drier and moister climate seems more serviceable for our purpose, and is used throughout the study. In some instances, the expressions dry and moist climate are used for the more extreme conditions. Drier climate can be defined as one in which insufficiency of moisture is the principal limiting factor for best yields of small grains. The plants suffer more or less frequently and more or less strongly from actual drought. Grain production under these conditions has to be carried on rather extensively. Increases of yields by application of nitrogen in any form (manure, green manure, or commercial fertilizer), if any, are moderate, mostly on poor soil; and negative results frequently are obtained from such applications. Breeding is carried on with a view to develop strains using as little water as possible and least susceptible to damage by drought.

Drier regions include semiarid and a large portion of sub-humid areas of the general classification. The remaining sub-humid and the humid areas comprise our moister regions. We use the phrase "dry regions" to refer to the more extreme portions of the drier regions; our dry regions in fact roughly coincide with semiarid areas of the general classification. Correspondingly the phrase "moist regions" refers to the more extreme portions of the moister regions and moist regions roughly coincide with humid areas of the general classification.

As with temperatures, quite different characteristics of the grains are needed to enable them to adjust to the manifold moisture conditions. The ability to produce a fair yield with little moisture, and genuine drought resistance,³ are the properties whereby a grain wins a place in production in dry regions. With increase in the supply of moisture, the property of making efficient use of additional moisture becomes increasingly important. With a still larger supply of moisture, abil-

³ See pp. 288-89 on drought resistance in the strict sense of the term.

ity to withstand an excess of moisture enters as a factor in the competition among grains.

Corn needs the smallest amount of water per weight unit of total dry matter, but is somewhat reluctant to make vigorous progress and produces relatively much stover where soil moisture is near the minimum. In utilizing water in excess of the minimum, it is superior to all other grains studied here in terms of grain. Among small grains, barley needs the smallest amount of water per weight unit of grain, but utilizes additional moisture less efficiently than the other grains. Oats do relatively best in abundant soil moisture, but as a spring grain oats also do better in drier conditions than is in agreement with their reputation as the crop of cool moist climates. Rye needs the largest amount of water per weight unit of grain. Wheat occupies an intermediate position; it requires at least as much moisture per weight unit of grain as oats, but, as a winter crop, is second only to barley in making progress in drier conditions. Wheat also adjusts itself relatively well to much soil moisture.

Seasonality of the water supply is another significant factor in the competition among grains. Fall-sown grains are usually better supplied with moisture owing to the small evaporation during the cold season. In the so-called Mediterranean and similar climates, indeed, the competition is entirely limited to fall-sown grains; and corn is out of the picture, unless the land is irrigated. It is fortunate for barley that such a seasonality is found in regions with warmer climate where this grain also can be sown in the fall (or winter).⁴

It is to a considerable extent due to the differences in moisture requirements that about two-thirds of the world wheat production and a slightly smaller percentage of barley production are grown without irrigation in drier regions, while only about 20 per cent of oats, and an even smaller proportion of rye, are so grown.

⁴The climates of the regions with Mediterranean climate are mostly also sufficiently mild for winter oats, but this grain makes little use of the opportunity.

TRANSPIRATION RATIOS

The water requirements in the narrow sense—transpiration ratios⁶—of different plants show large variations according to various students (Table 11). In part these variations

TABLE 11.—RANKING OF GRAINS ACCORDING TO WATER REQUIREMENT

(Pounds of water per pound of dry matter)

BRIGGS AND SHANTZ* COLORADO*	VON SEELHORST* GÖTTINGEN, GERMANY	BARNES AND HOPKINS† SWIFT CURRENT, SASKATCHEWAN
Millet 275	Wheat 333	Corn 227*
Sorghum 306	Barley 365	Oats 316
Corn 369	Rye 386	Barley 349
Wheat 507		Wheat 364
Barley 539		
Buckwheat 578	HELLRIEGEL* DAHME, GERMANY*	TULAIKOV† BESENTCHUK, SAMARA, RUSSIA
Oats 614	Barley 297	Corn 239
Rye 724	Wheat 359	Barley 382
	Rye 377	Wheat 415
LEATHER* PUSA, INDIA ^c	Oats 401	Oats 430
Corn 337		
Sorghum 437	KIESELBACH‡ NEBRASKA	RICHARDSON§ RUTHERGLEN, VICTORIA ^d
Barley 468	Milo (dwarf) . . . 264	Barley 350
Oats 469	Corn 267	Wheat 380
Wheat 554	Wheat (Turkey Red winter) . . . 323	Oats 390
	Oats (Kherson) . . 414	Rye 421
WIDTSOE* UTAH		
Corn 386		
Wheat 546		

* L. J. Briggs and H. L. Shantz, *The Water Requirement of Plants. II.—A Review of the Literature* (U.S. Dept. Agr., Bureau of Plant Industry Bull. 285, Oct. 6, 1913), p. 90. Data pertain to dry matter of total plant rather than grain only.

† S. Barnes and E. S. Hopkins, *Soil Moisture and Crop Production* (Canada Dept. Agr. Bull. 130, New Series, 1930), p. 41.

‡ T. A. Kiesselbach, "Varietal, Cultural, and Seasonal Effects upon the Water Requirement of Crops," *Proceedings of the International Congress of Plant Sciences*, 1929, p. 92.

§ A. E. V. Richardson, "Water Requirements of Farm Crops," *Journal of the Department of Agriculture of Victoria*, June 1923, XXI, 330.

* Spring grains.

^b Corn for silage.

^c Corn and sorghum spring-sown; other grains fall-sown.

^d All grains fall-sown.

⁶ The transpiration ratio is equivalent to the amount of water transpired by the plant per weight unit of dry matter of the plant. Usually only the part of the plant above the surface of the soil is considered in computing the ratios.

may be spurious, due to inadequacies of the testing techniques. Another part of the differences shown by the tests is brought about by the divergences between varieties of the same plants, all plants displaying more or less adaptation to regional variations in moisture supply. But the tests also reveal inherent divergences in the water requirements of different plants which tend to be present whatever the conditions under which the tests were made.⁶

Corn, sorghum, and millet transpire the smallest amounts of water per weight unit of dry matter. Investigators differ only with regard to the order in which these grains rank in this respect. According to Briggs and Shantz, the water requirement of sorghum and millet⁷ is less than that of corn, and Kiesselbach's findings support this view. Although the tests made in India show corn requiring far less water than sorghum, it seems fairly safe to assume that the water requirements of these three grains are rather close together, with corn probably needing slightly more than the other two.

All four of the principal small grains have substantially larger water requirements than corn,⁸ but there is disagreement as to their relative positions. It is rather generally accepted that the oat and rye plants have a higher transpiration ratio than the barley and wheat plants, but in the Canadian tests (Table 11) oats had a smaller transpiration ratio than either. According to Tulaikow, who experimented under con-

⁶ The tests are mostly performed in pots, and there is no reason to infer that the results would be exactly the same in natural environment.

⁷ Sorghum botanically is a class of millet, milo a subspecies of sorghum.

⁸ The recently published results of experiments at Mandan, North Dakota, extending over 20 years and therefore deserving much attention, show a great superiority of corn over wheat in the amount of water used per weight unit of dry matter. The field water requirement—including evaporation of water from the soil, loss through run-off and the like, in addition to the moisture transpired by the plant—per 1,000 pounds of field-cured total matter (for wheat including weeds) averaged in 1915-34, in inches of precipitation:

Practice	Wheat	Corn
Continuous cropping, spring plowed.....	5.97	2.35
Alternate cropping and fallow.....	3.77	2.66

While in alternate cropping wheat needed 42 per cent more water, it needed two and a half times as much in continuous cropping. See J. C. Thysell, *Conservation and Use of Soil Moisture at Mandan, North Dakota* (U.S. Dept. Agr. Tech. Bull. 617, June 1938), p. 29.

ditions rather resembling those at Swift Current, Saskatchewan, barley stood lowest, with oats requiring more water than either barley or wheat; but the difference in water requirement between all three grains was not very large. In Kiesselbach's findings the transpiration ratio of wheat was much less than that of oats. In spite of the discrepant findings, the evidence affords reasonable support for the following ranking of the small grains in water requirement (from smallest to largest): barley, wheat, oats, and rye; or barley, wheat, rye, and oats.

This ranking, however, applies to the whole plants. Differences in straw-grain ratios introduce some modifications. If the transpiration ratio is computed per unit of grain only, barley stands even lower in water requirement as compared with the other small grains, oats mostly are more economical of water than wheat, and rye is even less economical.

Winter grain has a higher straw-grain ratio than spring grain, but its *field* water requirement is nevertheless much less per weight unit of grain, since its growing period falls in the cooler part of the year.

As we have seen, corn tends to have a low straw-grain ratio where yields are high, and vice versa.⁹ Hence corn makes a very favorable showing with regard to the amount of water transpired per unit of grain in regions where yields are high and water supply large, while a large part of this superiority, perhaps all of it for some varieties, disappears where water is urgently needed.

Ten centals of air-dry grain per acre and a straw-grain ratio of 150 are equivalent to a total crop of approximately 1.1 short tons on a dry-matter basis. With a transpiration ratio of 350, the total amount of water transpired by such a crop would be equivalent to 385 tons or slightly less than 3.5 acre-inches.¹⁰ Where the total annual precipitation is equivalent to say 15 inches, it is not easy for the plant to find such a

⁹ A 15-bushel corn crop is likely to have a total weight of 2,500 to 3,500 pounds in the Northern Great Plains. In the Corn Belt a 40-bushel crop may have a total weight of some 4,750 to 6,000 pounds. Thus a crop of corn grain larger by 165 per cent has a total weight larger by only 70 to 90 per cent.

¹⁰ One acre-inch is equal to 113 short tons of water.

quantity of water available from the precipitation falling during the growth of the plant and that stored in the ground. Barnes and Hopkins¹¹ showed that, in years when precipitation was somewhat in excess of 15 inches, both on stubble and fallow land the water supply to a depth of five feet of soil up to the time of maturing of spring wheat was worked down to less than one inch of available water¹² (one-half inch on the average), while sweet clover at harvesting time left even less. According to Thysell,¹³ on the average in 1915-34 only 0.70 inches of water was available at time of harvest of continuous wheat to a depth of six feet of soil at the Mandan Experiment Station, North Dakota, over the "normal point of field reduction," which is considered to be ". . . an approximate measure of the lower limit of available water. . . ." ¹⁴ The proportion of the annual precipitation which is effectively used by plants is considerably larger than in the above examples only where fall-sown grains are grown on precipitation coming down in the cold season.

Under such conditions even a moderate difference in transpired water between plants may be significant. Reference to the distribution of grain production over the world, in fact, shows that the variations in the transpiration ratio are not without considerable effect. All kinds of millets are typical plants of dry regions. Of the four principal small grains, barley, the grain with the smallest transpiration ratio, encroaches on deserts more than any other grain, while oats and rye are grown primarily in moister regions.

Differences in the transpiration ratio are of course particularly important in regions with little precipitation. Yet even there other factors considerably modify the outcome of competition. The large superiority of corn over the four small

¹¹ S. Barnes and E. S. Hopkins, *op. cit.* (under Table 11), p. 31.

¹² Available water is water which can be used by the plants.

¹³ J. C. Thysell, *op. cit.*, pp. 7, 17.

¹⁴ The figure in the text is for spring plowing; for fall plowing the average of available water was less than the "normal point" by 0.24 inches. The average annual precipitation at Mandan, in the years covered by the study, was 15.11 inches. In cropping of wheat alternated with fallow, 1.77 inches were available on the average at harvest time.

grains in the amount of water transpired per weight unit of dry matter fails, owing to offsetting influences, to ensure it a very strong position in dry regions.

Other than the transpiration ratio, factors important for the ability of plants to produce a crop with little water are the ability of grains temporarily to withstand absence of water; their ability to yield relatively satisfactorily at a low water saturation of the soil; and, last but not least, the seasonality of water requirement of different plants. For corn the unfavorable stover-grain ratio under drier conditions is also important.

MOISTURE SATURATION OF SOIL

Plants display minimum and optimum requirements with reference to moisture saturation of the soil, as in the case of warmth. But an increase in warmth requirement from minimum to optimum enhances both yield and quality of the grain, whereas an increase in moisture from minimum to optimum always increases yield but improves the quality of some grains while injuring the quality of others.

It is even more important that the optimum requirement for warmth of grains—at least of small grains—does not much exceed the minimum requirement, while in the case of moisture the optimum is at least twice the minimum. Relatively little grain is produced in the world with a supply of warmth below the optimum, but much more than half of the total and perhaps more than three-quarters of it is produced with the moisture supply below the optimum. Hence the efficiency in utilizing warmth greater than the minimum and up to the optimum, and the variations in this efficiency from one grain to another, are relatively insignificant for competition of grains with other crops or among themselves. Efficiency in utilizing additional moisture, however, is at least as important as the ability to produce a fair crop with a small amount of water (including genuine drought resistance); and it is more important than the ability to withstand an excess of moisture over the optimum requirement, not only for compe-

tition of the grains among themselves but especially for their competition with other crops.

It was once believed that plants differ widely with respect to the minimum point to which the moisture content of the soil can be reduced before permanent wilting occurs, and that drought resistance is in part due to the additional supply of water which is available to some plants through the greater force which they exert upon the soil moisture. But the investigations of Briggs and Shantz¹⁵ led them to "conclude that the differences exhibited by plants in this respect are much less than have heretofore been supposed and are so small as to be of little practical utility"

There is, however, a material difference between plants in that some can remain for some time under a regime of unavailable water and start growth again after the soil receives new moisture, whereas other plants adjust themselves to shortage of soil moisture in such a way that ripening is hastened and may be even completed (prematurely) before the supply of available water is definitely exhausted; no recovery, however, is possible for such plants after they have been for a time under the regime of unavailable moisture. All the small grains studied here—wheat, rye, barley, and oats—belong in the second group. Corn, and especially all kinds of millets including sorghums, the grains with the smallest water requirements, diverge also in that they are not killed under the regime of unavailable moisture, but adjust themselves to a dormant state from which they can return to active life after the supply of water in the soil is replenished. If the expression "drought resistance" is used in the strict sense of the word, these grains alone have this ability.¹⁶ The millets are far

¹⁵ L. J. Briggs and H. L. Shantz, *The Wilting Coefficient for Different Plants and Its Indirect Determination* (U.S. Dept. Agr., Bureau of Plant Industry Bull. 230, Feb. 3, 1912), p. 74.

¹⁶ S. Barnes and E. S. Hopkins (*op. cit.*, p. 42) have experimented with the behavior of wheat, oats, barley, and corn under the regime of unavailable water at Swift Current, Sask. "Wheat, oats and barley have failed to make any recovery [after the status of unavailability of water was once reached]. These crops appear to adjust their growth as the water supply diminishes. When the low level has been reached the grains have headed out and have usually produced a small quantity of seed. Corn being essentially a dry land crop has withstood a long period without rain and has made fair recovery after the addition of water."

superior to corn in the ability to withstand a period of unavailable water; this ability in fact is so small in the case of corn that some students ascribe it to millets only.

Grains vary also in the amount of progress they are able to make at a soil moisture above but close to the wilting point. The behavior of corn is particularly conspicuous. It is a familiar observation that corn is reluctant to extract moisture from a none-too-plentiful source.¹⁷ This observation is greatly fortified by the results of tests at Mandan, North Dakota.¹⁸ The following amounts of water, in inches, were on the average available in the first six feet of soil over the normal point of field reduction of moisture at harvest time:

Practice	Wheat	Corn
Continuous cropping, spring plowing.....	0.70	2.95
Continuous cropping, fall plowing.....	-0.24	3.20
Alternated cropping	1.77	3.85

The reluctance of corn to make use of small supplies of water is of paramount importance for explaining the failure of corn to realize fully upon the large advantages that it possesses in the small amount of water transpired per weight unit of dry matter and in the ability to survive a period of unavailable water. The same reluctance, moreover, throws light on phenomena such as the following, which hardly can be explained in full by other factors: (1) the higher yields of small grains following corn in the rotation in drier regions, as compared with yields obtained after small grains; (2) the fact that in drier regions corn usually does much better in continuous cropping than in rotation with small grains; and (3) the fact that fallowing does not increase yields of corn as much as those of small grains.

Grain crops also display material differences in the optimum saturation of the soil with moisture. Experiments by

¹⁷ See, for example, H. A. Wallace and E. N. Bressman, *Corn and Corn Growing* (already cited), p. 361. For a discussion of the adaptability of corn to drier conditions see also A. J. Henry and others, "Weather and Agriculture," *Agriculture Yearbook*, 1924, pp. 509-10.

¹⁸ J. C. Thysell, *op. cit.*, p. 18.

Adolf Mayer¹⁹ showed that the water saturation of the soil at which the yields of the principal small grains were highest was as follows, in per cent of maximum:

Oats	90
Wheat	80
Rye	75
Barley	62

Thus oats do best at such a large moisture content of the soil that the other small grains are thereby damaged.²⁰ The optimum saturation of the soil for corn seems to be lower than that of oats and may also be lower than that of wheat. According to Kiesselbach,²¹ the optimum water saturation of the soil for corn lies at approximately 70 per cent. Unfortunately the findings of Mayer and Kiesselbach cannot be compared because they seem to have employed different methods of determining the water saturation of the soil.

The fact that one crop possesses a higher optimum water saturation than another does not imply that the first crop utilizes the water available above the minimum better than the second. The difference between yields as obtained at the minimum and at the optimum water requirements may be larger for the second crop, although its optimum requirement is somewhat less. Unfortunately we do not have strictly comparable experimental data on the behavior of different grains at different degrees of water saturation of the soil. None of the small grains is very efficient in utilizing water above a quantity rather near to the minimum required for keeping up growth. This explains the strength of small grains in drier regions and their subordinate position in moist climates. The difference between the yields obtained at the saturation near the minimum and at the optimum saturation is least for barley and probably largest for oats.

¹⁹ As reported by D. N. Prjanischnikow, *The Field Crops* (already cited), p. 51.

²⁰ According to Wollny, the yield of barley at 80 per cent saturation of the soil was 83.3 per cent of the yield obtained at a 40 per cent saturation. See Fritz Christian-sen-Weniger, *Die Grundlagen des türkischen Ackerbaus* (Leipzig, 1934), p. 169.

²¹ T. A. Kiesselbach, "Varietal, Cultural, and Seasonal Effects upon the Water Requirement of Crops" (already cited under Table 11), p. 99.

It should be accepted that corn is able to utilize supplies of soil moisture above the bare minimum better than any small grain, even oats, in terms of grain. According to Kiesselbach,²² at a 50 per cent water saturation of the soil, corn yielded 45 per cent more than at a 40 per cent saturation. But the increase of the saturation to 70 per cent brought about a further increase in yield by only slightly less than 5 per cent. The superiority of corn in utilizing additional water is the consequence of its reluctance to make good progress at a soil moisture near the minimum, of the considerable improvement of the stover-grain ratio under more favorable growing conditions, and, last but not least, of its high yielding power as measured in yield of corn grain. Owing to this power, corn, though not at its best, may still be best; but the great yielding power of corn is realized fully only with soil moisture near to the optimum.

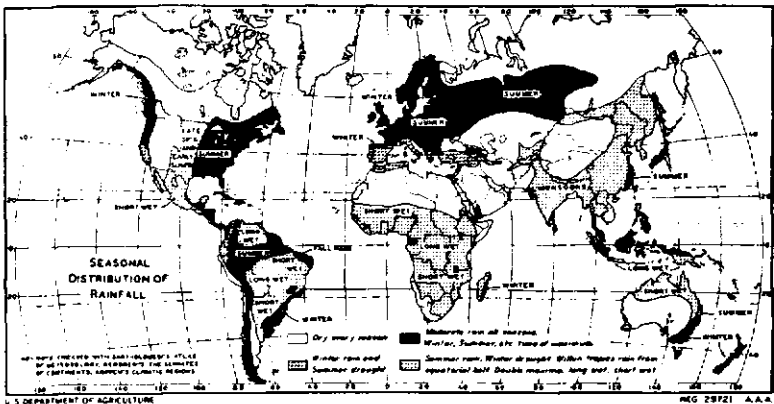
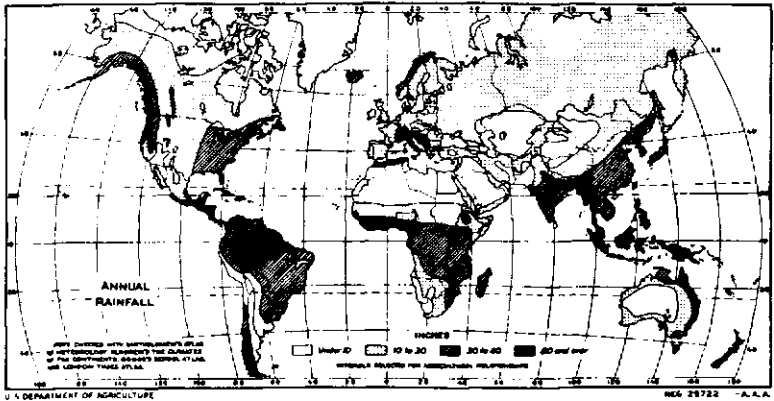
No comparable experiments on the behavior of grains under a soil moisture above the optimum are at hand. But the differences in the optimum saturation of the soil for different grains contribute much toward explaining the differences in yields of different grains obtained in moist climate. Oats have the highest optimum water saturation of the soil. Hence they continue to improve in yield when other grains are affected by excessive water. The much higher optimum saturation of the soil for oats as compared with barley, for example, would probably make oats superior for moist climates, even if the soil in such climates did not incline strongly toward acidity.

SEASONALITY OF PRECIPITATION

The lower section of Chart 40 conveys an idea of the seasonal distribution of precipitation in the world. Predominance of summer precipitation is widespread in areas devoted to grain production. Yet in general fall-sown grain is more favored by the seasonality of precipitation than is spring-sown

²² *Ibid.*, p. 99.

CHART 40



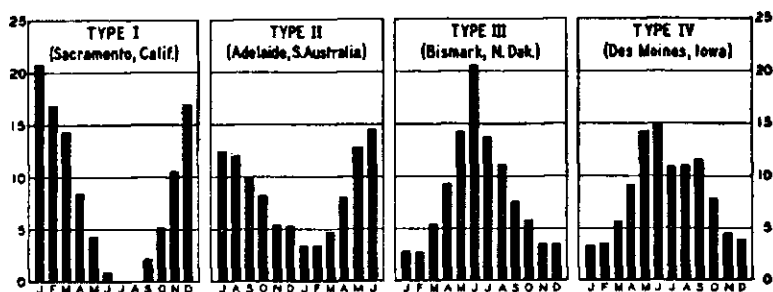
grain. For the water requirement of the plants in the cold season is very small, and the effectiveness of an inch of moisture in the cold season is much greater than that of an inch coming in the hot season.²⁸

The so-called Mediterranean climate (winter rain and summer drought, as illustrated in Chart 41 by data from Sacramento, California) excludes spring grain except under irrigation. It is found only in a few regions of the world, but these happen to be fairly important in grain production. They comprise mainly areas bordering on the Mediterranean (north-

²⁸ Freezing of the ground involves some substantial modifications.

CHART 41.—SOME IMPORTANT TYPES OF SEASONAL DISTRIBUTION OF PRECIPITATION*

(Monthly precipitation in percentage of annual precipitation)



* The types are as follows: (I) Mediterranean climate; (II) predominantly winter precipitation; (III) predominantly summer precipitation, steep type; (IV) predominantly summer precipitation, flat type.

ern Africa, almost all of Spain, Portugal, and Italy, a small portion of France, and parts of the Balkan Peninsula, and Asia Minor), California, the grain belt of Western Australia and a portion of the South Australian grain belt, the central valley of Chile, and a little of South Africa.

Spring-sown grain is not grown or is extremely handicapped also in several regions other than those of typically Mediterranean climate. First come regions which have the larger part of their moderate total precipitation in the winter; in Chart 41 this type of seasonality is illustrated by the precipitation at Adelaide, South Australia.²⁴ The summer rains of these regions are mostly insufficient to produce fair crops of spring-sown grains. Almost all of the Australian wheat belt lying outside of the Mediterranean climate, and a large portion of the Columbia River Basin, are the most important of these regions for grain production. In the Pacific Northwest, however, the effect of the seasonality of precipitation on the competition of fall-sown and spring-sown crops is largely offset by an exceptionally high water-holding capacity of the soil.

Since evaporation is low in the cold season, a rainy autumn under certain conditions proves as efficient as winter rains

²⁴ Some students class the seasonality of Adelaide as that of a Mediterranean climate.

for fall-sown grain. Provided these autumn rains occur in a region with a warm climate, occasional rains in the cold season suffice to bring the fall-sown grain to maturity. If such a region does not have any spring and early-summer rains, as is the case in most of the area devoted to the production of wheat and barley without irrigation in British India, unirrigated spring-sown grain is excluded as in the Mediterranean climate.

In colder climates spring and early-summer rains are needed for such fall-sown grain in addition to autumn rains. Where spring, summer, and autumn rains are available, spring grains can of course be grown along with fall grains. But provided winter precipitation is not too scanty, fall-sown grain retains in drier and hotter climates an advantage in addition to that possessed by it under moister conditions. The situation in central and western Kansas, where winter precipitation is scanty, shows that even under such conditions fall-sown grain is not in a worse position than spring grain so far as concerns moisture needed for the growth of the plant. Late-summer rains are used to plant the crop in the fall in a relatively moist seedbed. Spring and early summer rains bring it to maturity.

Scanty winter precipitation, it is true, results in heavy winterkilling of wheat in areas like Kansas, while in South Dakota and farther north its effect combined with that of low temperature makes production of winter wheat impossible. In western Canada, the small winter precipitation does not permit winter rye to penetrate as far north as spring wheat.

Outside of the regions where winter grain cannot be grown, or is heavily winterkilled owing to lack of snow cover, fall-sown grain is rarely in a worse position than spring-sown grain with regard to moisture supply. Manchuria is one of a few such regions. Here heavy rains fall at the very time when winter wheat matures, necessitating the growth of later maturing spring wheat.²⁵

Where fall-sown grain is favored by the seasonality of pre-

²⁵ Low winter temperatures and insufficient snow cover are also factors.

precipitation over spring-sown grain, the advantage is usually the larger the earlier the crop matures. Early maturity is of course particularly important in regions with Mediterranean climate, or in those having heavy rains in the fall but none in the spring. Barley, which matures or at least develops ahead of the other grains, outyields the others heavily under such conditions, but fall-sown oats, which mature ahead of fall-sown wheat, seem not to be in a better position than the latter.

In drier regions, not only fall-sown but also spring-sown grains have to rely heavily on moisture accumulated in the soil during the fall and winter, even where precipitation is relatively ample in the spring and summer and relatively scanty in the fall and winter. Under such conditions, earliness is as important to spring-sown grains as to fall-sown, and sometimes even more so. Barley again is the crop which gains most from this, with oats occupying second place.

Thus far we have considered only small grains. Compared with them, corn has both important disadvantages and an important advantage with regard to seasonal water requirement. Being sown late, it cannot use the moisture accumulated during the cold season so efficiently as small grains. More than any other of the grains studied, corn depends on late spring and summer rains. Moreover, the time at tasseling, when the water requirement is largest, is extremely critical. Wallace and Bressman write:²⁶ "In Ohio, Indiana, Illinois, Missouri, Kansas, Nebraska and southern Iowa, the rainfall and temperature during the ten days before and the twenty days following tasseling time have more to do with corn yield than the weather at any other period. Ideally, there should be 4 or 5 inches of rainfall during this thirty-day period . . ."

The advantage of corn over small grains is that it efficiently utilizes rain coming in late summer and—in higher latitudes—that of the early fall which is too late to help the small grains and, if abundant, even reduces both the quantity and quality of the small-grain crops. Part of the rain coming

²⁶ H. A. Wallace and E. N. Bressman, *op. cit.*, p. 302.

too late for a particular year's crop of the small grains can, it is true, be stored and utilized for the crop of the next year, but utilization as efficient as in the case of corn cannot be attained, especially so far as spring-sown small grains are concerned.

INDIVIDUAL COMPARISONS

Owing to considerations of space, individual comparisons are limited to the analysis of the competition between wheat and barley, and between wheat and corn. The fact that the behavior of different grains under dry heat was discussed in chapter xi is another reason, for the behavior of crops under dry heat and in soil with little moisture is interconnected.

It was demonstrated, for example, that in dry heat spring barley tends to outyield spring oats considerably, and that the advantage of fall-sown barley over fall-sown oats is even greater. Barley evidently could not have those advantages in regions where moisture is scarce, unless it were able to do relatively well with available soil moisture near the minimum and needed less moisture than oats per weight unit of grain. The fact that the requirement of barley for moisture is relatively great in the earlier stage of growth, when soil moisture is more plentiful, is also a factor. Since barley tends to outyield oats more or less heavily in drier regions and at best yields little more than oats in moister regions, no further proof of the much smaller ability of barley to utilize additional water seems to be needed.

The advantage of winter wheat over winter rye in dry heat (see p. 274) would also be lacking if wheat did not transpire materially less water per weight unit of grain than rye; but the later maturity of wheat as compared with rye is a partly offsetting factor. The fact that the optimum saturation of the soil seems to be higher for wheat than for rye frequently fails to be reflected in yields, because of the tendency of the soils receiving much moisture toward excessive acidity.

Wheat versus barley.—Fall-sown barley has a large ad-

vantage in yield over fall-sown wheat in drier climate. Data from the California Experiment Station showing 39 per cent excess of yields of barley over wheat were cited in discussing the ability to withstand dry heat. Moreover, the less precipitation, the larger seems to be the advantage of fall-sown barley.

Data for Tunis, shown in Chart 42, strikingly manifest the large extent to which competition of fall-sown wheat depends on the amount of precipitation. While the barley acreage amounted to only 30 per cent of the wheat acreage in region I, it was two and one-half times as large in the driest region (Military Territory).²⁷ The predominance of barley in the interior of Tunis, it is true, can be traced in part to the fact that this grain is grown to a large extent by the natives, while wheat is preferred by European colonists; but the moisture supply is probably the most pertinent factor. It is of interest to add that in the northern part of Tunis about 18 per cent of the total acreage was in crops other than wheat and barley, while in the Military Territory 99.7 per cent was in these two crops. The situation in Algeria and Morocco is the same as in Tunis.

Van Valkenburg²⁸ writes of the competition between barley and wheat in British India: "barley is crowded out upon the less fertile soils, or on the more inadequately watered soils" "Most of the barley is grown on the plains of the United Provinces . . . where winter rains are not so copious as along the east of the Himalayas and on the Punjab side of the Indian Desert where lack of moisture prevents the

²⁷ The situation had to be illustrated by acreages rather than by yields, because no data on yields in subdivisions as small as those used in the chart are available. In larger subdivisions the yields averaged in 1926-35, in quintals per hectare:

Grain	Northern	Central and Southern
Wheat, common	11.3	5.5
Wheat, durum	4.9	2.0
Barley	5.2	3.3

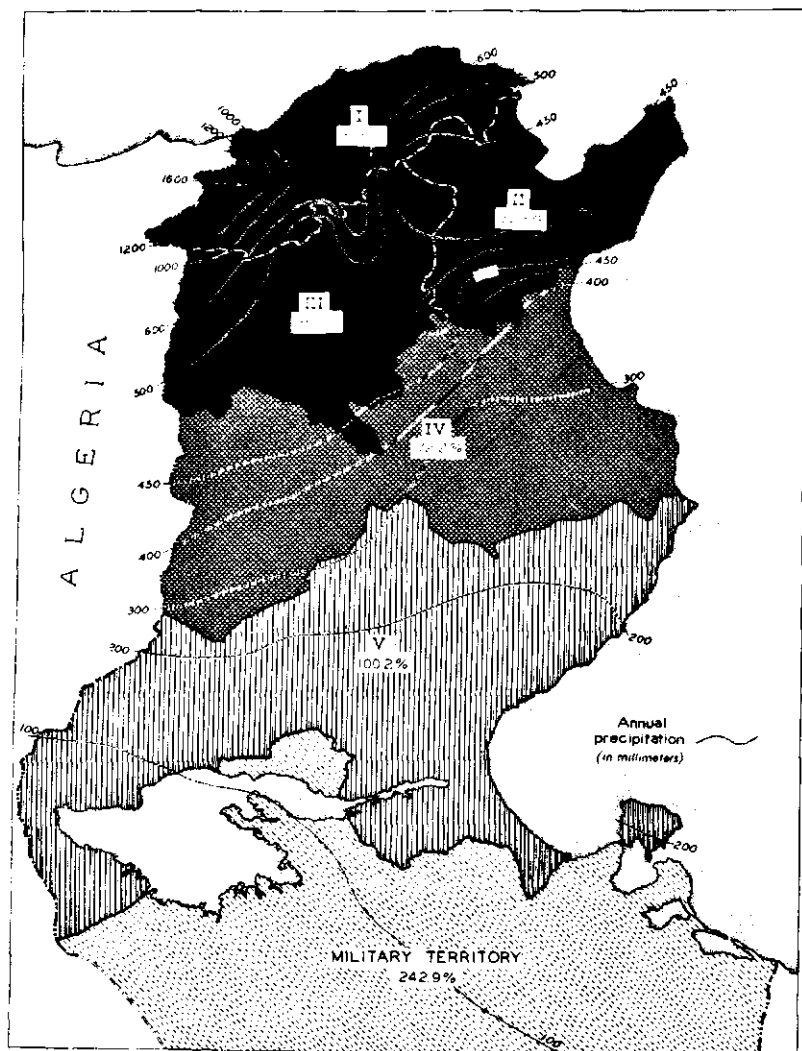
While the yield of barley in central and southern Tunis was 37 per cent less than in northern Tunis, the yield of wheat in the drier portion of the country was less than half of that obtained in the portion somewhat better supplied with moisture.

²⁸ Samuel Van Valkenburg, "Agricultural Regions of Asia: Part IV—India" (already cited), p. 135.

COMPETITION AMONG GRAINS

CHART 42.—ACREAGE RATIOS REFLECTING EFFECT OF PRECIPITATION ON COMPETITION BETWEEN BARLEY AND WHEAT IN TUNIS*

(Barley acreage in percentage of wheat acreage)



* Based on acreages of 1936-37, which were kindly supplied by the Direction des affaires économiques, Régence de Tunis.

germination of wheat except under irrigation." The great predominance of barley in the driest regions justifies the recurring statement that barley comes nearer to the desert than any other grain. It is correct, however, merely for regions where only fall-sown grains can be grown.²⁹

The situation in Australia, however, does not fit with the generalization that modest precipitation of the Mediterranean type greatly favors barley, although moisture conditions in Western Australia and in part of the South Australian grain belt are very like those in California or northern Africa. The small Australian acreage in barley consists almost entirely of malting barley, and is concentrated in a small area in South Australia better supplied with moisture than the regions producing wheat.³⁰ Australia, of course, is a new country. Weediness, which is a factor in the shift from wheat to barley in California and is likely to be still more important in this regard in northern Africa, is hardly significant in Australia. The slower rise in temperature in the spring in the Australian grain belts may be a further factor explaining the apparently weak competitive power of barley. Moreover, even good yields of feed barley would not make it possible for distant Australia to export this cheap grain. Since a large proportion of oats is harvested for hay, it may also be of some importance that oats will produce more hay than barley, even though yields of grain are the same. Nevertheless, if there is no factor unknown to the writer, one would expect that barley (both for grain and hay) will play a greater role on that continent in the future.

Yields of spring-sown six-row barley also are in general

²⁹ On the similar situation in the Near East of Asia see Samuel Van Valkenburg, "Agricultural Regions of Asia. Instalment I," *Economic Geography*, July 1931, VII, 233; in Egypt, I. E. Nagy, *Die Landwirtschaft im heutigen Ägypten* (already cited), p. 103; and in Yugoslavia, Otto v. Frankeš, *Die sozialökonomische Struktur der jugoslawischen Landwirtschaft* (already cited), p. 27. The large acreage in barley in Spain also indicates that fall-sown barley is the grain most adapted to the drier parts of the Mediterranean climate.

³⁰ In 1934-35, 455,921 acres were in barley, or 2.2 per cent of the total crop area. Of the barley area, 87 per cent was in malting barley. Of the total Australian barley acreage, 69 per cent was in South Australia. *Official Yearbook of the Commonwealth of Australia*, No. 29-1936 (Canberra, 1936), p. 673.

affected materially less by insufficient moisture than are yields of spring wheat.³¹ The superiority of the earlier-maturing barley is particularly marked in regions where the spring crops rely heavily upon moisture accumulated prior to seeding. Talanow and Kusmin write on the situation in Russia: The third area where barley has to retain its large significance . . . is the semiarid steppe of the south and southeast of the Ukraine, Crimea, and the semiarid portion of North Caucasia, and of the southeast of the Central Blacksoil Area. There, owing to its large drought resistance, barley returns higher and more stable yields than oats and outyields spring wheat by 50 to 100 per cent.³²

The great superiority of spring barley over spring wheat is also clearly marked throughout the northern portion of the Great Plains. Barley outyielded wheat by 29.2 per cent in North Dakota and by 42.9 per cent in South Dakota (averages for 1923-32).

The balance shifts materially in favor of wheat, where spring grains must rely heavily on precipitation accumulated in the cold season, and where winter wheat but no winter barley can be grown. This can be demonstrated by yields in parts of Russia where the position of barley is strong as compared with that of spring wheat but the climate is not too severe for winter wheat. The data are as follows, in poods per dessiatine (averages for 1901-10):³³

District	Spring wheat	Barley	Winter wheat
Bessarabia	48	62	58
Kherson	40	51	47
Taurida	33	46	48
Terek	46	58	58

³¹ Little two-row barley is grown in such conditions.

³² W. W. Talanow and W. P. Kusmin, "The Requirements of Individual Crops as to Growing Conditions and the Possibility of their Expansion and Shifts to Certain Regions of the USSR," *The Crops of the USSR* (already cited), p. 71. The reader may note a contradiction between this statement and the fact that barley is mentioned only once among the leading crops in Chart 22 (p. 217), especially since Chart 22 reproduces a chart from the same source as that from which the quotation has been taken.

³³ Russia, Direction générale de l'Organisation agraire et de l'Agriculture, Division d'Economie rurale et de Statistique agricole, *Recueil de données statistiques et économiques sur l'industrie agricole en Russie et dans les pays étrangers* (Petrograd, 1915), 8th year, pp. 67, 76. No data for small territorial subdivisions in recent years are available to the writer.

Thus spring barley yielded only slightly more than winter wheat on the average. In spite of this, the proportion of the acreage in barley in those districts was large before the war and still continues so. There are of course some managerial gains from growing winter wheat and spring barley rather than winter wheat alone. But backwardness of producers and unfounded hesitation to grow winter wheat continuously seem also to be factors. That this is so can be seen from a comparison of the situation in southern Russia with that in the hard-winter-wheat region of the United States. *Ceteris paribus* one would expect to find in the latter barley a little stronger relative to winter wheat, because a slightly smaller fraction of precipitation comes in the cold season. Data on yields in Nebraska and Kansas in Table 12 in fact appear to indicate

TABLE 12.—YIELDS OF ALL WHEAT IN PERCENTAGES OF BARLEY YIELDS IN SPECIFIED STATES BY CROP-REPORTING DISTRICTS*

State	District	Western	Central	Eastern
North Dakota ...	{ Northern	80	82	88
	{ Central	75	79	78
	{ Southern	73	73	69
South Dakota ...	{ Northern	75	72	73
	{ Central	88	77	65
	{ Southern	83	77	68
Nebraska	{ Northern	78	87	86
	{ Central		85	85
	{ Southern		82	79	97
Kansas	{ Northern	69	91	93
	{ Central	81	87	96
	{ Southern	81	82	92

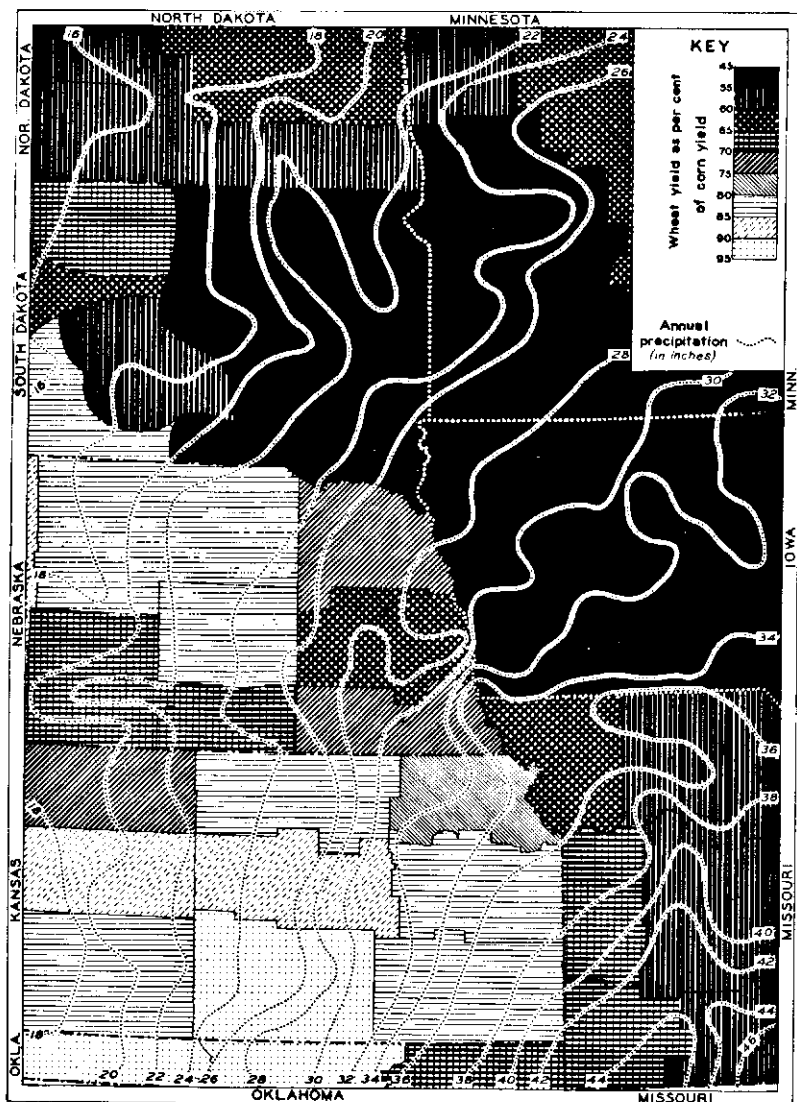
* Official data; for South Dakota, averages of 1924-35; on years for other states see Appendix Note B.

that the ratios of winter wheat to spring barley are less favorable to winter wheat in the hard-winter-wheat region of this country than in southern Russia. Yet only a little barley is grown in the former.

Furthermore, data in Table 12 leave no doubt that the com-

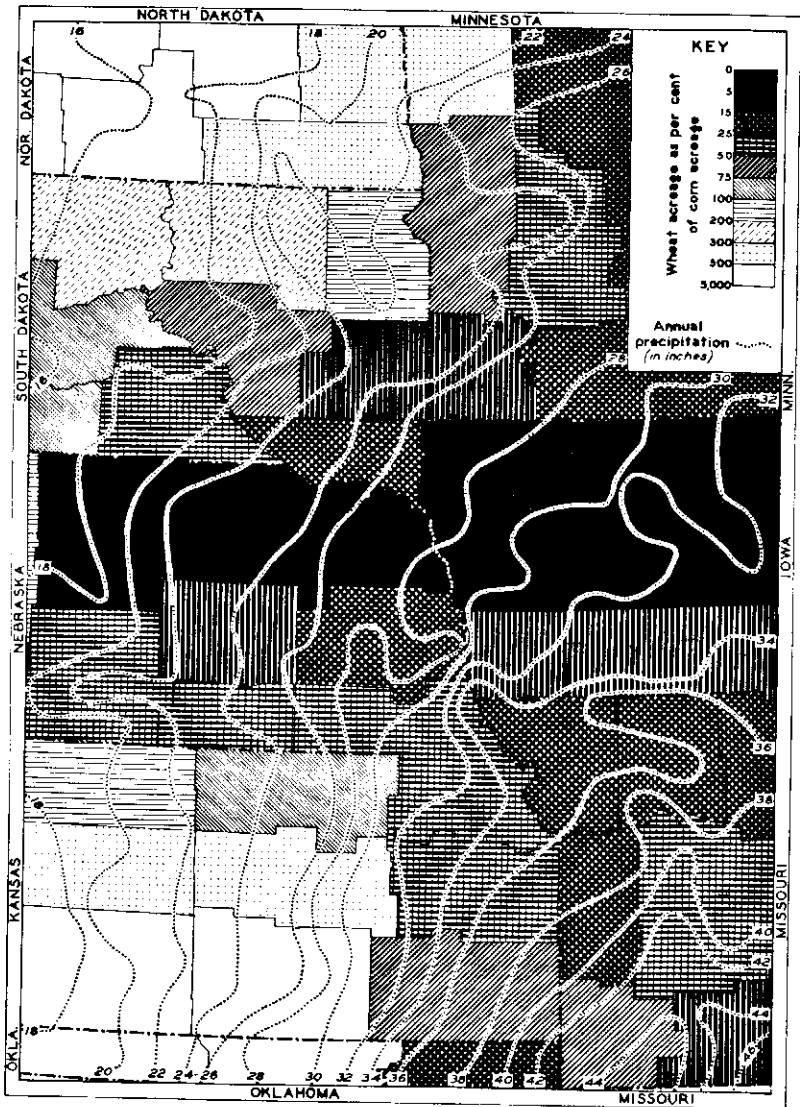
COMPETITION AMONG GRAINS

CHART 43.—RATIOS BETWEEN YIELDS OF WHEAT AND CORN IN A PORTION OF THE UNITED STATES*



* Official data. For details, see Appendix Note B.

CHART 44.—RATIOS BETWEEN ACREAGES OF WHEAT AND CORN IN A PORTION OF THE UNITED STATES*



* Official data. For details, see Appendix Note B.

petitive power of wheat against spring barley in the hard-winter-wheat region is greater than in the hard-spring-wheat region.³⁴ The actual difference in the ratios of yields of wheat to those of barley in favor of the regions growing winter wheat is probably even a little larger than appears from the data in the table, because fallow, used almost exclusively for wheat, seems to be more common in the regions growing spring wheat.

Corn versus wheat.—In regions where temperature conditions are not an obstacle to production of both corn and wheat, and where moisture is ample and well distributed for corn, this grain is the strongest competitor of wheat even in distant regions and on soils best adapted to wheat. Charts 43 and 44 present the situation in a portion of the United States which is transitional from full dominance of corn to almost no corn at all. As shown in Chart 43, corn outyielded wheat in every crop-reporting district. The mere fact of higher corn yields is of course insignificant for the competition between the two grains, for in surplus regions corn generally needs to outyield wheat substantially in order to compete effectively. But corn actually attains this superiority over a wide area. In the heart of the Corn Belt it yields more than twice as much as wheat. Corn yields exceeding those of wheat by 60 per cent or more are obtained far beyond the regions where corn is at its best. In a large portion of the western fringe shown in Charts 43 and 44, however, the superiority of corn in yielding power falls to only 10–25 per cent.³⁵

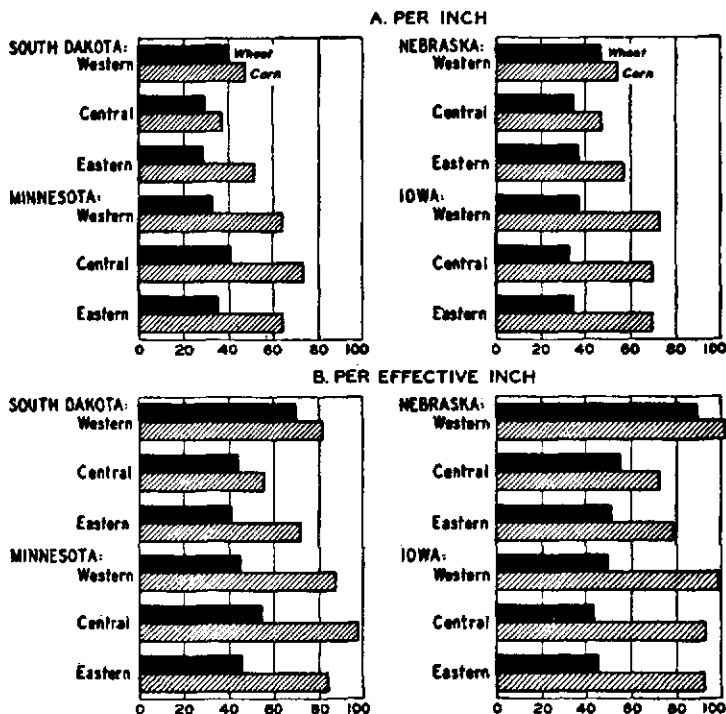
The principal reason for the large divergence in the ratios between the yields of corn and wheat in the Corn Belt and west of it is undoubtedly the greater ability of corn to utilize additional supplies of water.³⁶ Chart 45 seeks to give a quantita-

³⁴ The very favorable showing made by barley yields in northwestern Kansas is an exception and would need further analysis.

³⁵ The considerably more favorable data for western North Dakota are hardly significant. Corn is grown there largely for silage, and yields of corn grain as given by statistics are arbitrary figures. On doubts concerning yields of corn grain in North Dakota see F. F. Elliott and others, *Types of Farming in North Dakota* (U.S. Dept. Agr. Tech. Bull. 102, December 1923), p. 13.

³⁶ A plentiful supply of moisture seems in particular to be relatively more important to corn than a plentiful supply of nutrients, while the opposite is true of wheat.

CHART 45.—RELATIVE EFFECTIVENESS OF WHEAT AND CORN IN THE USE OF PRECIPITATION, IN SPECIFIED STATES*
(Pounds of grain yield per unit of rainfall)



* Western, central, and eastern South Dakota and Iowa comprise the three western, central, and eastern crop-reporting districts, respectively. For Minnesota the arrangement is similar except that the three northern crop-reporting districts have been omitted. Nebraska West consisted of crop-reporting district 1, less Scotts Bluff (omitted because of much irrigated acreage). Central Nebraska is composed of crop-reporting districts 2, 5, 7, and 8; and eastern Nebraska of districts 3, 6, and 9.

The same yields and acreages have been used as in Charts 43 and 44, except for yields of South Dakota. For the latter state, data by crop-reporting districts for the period 1924 to 1935 have been used, with an upward adjustment of corn yields by 16 per cent to offset the effect of weather conditions especially unfavorable for corn in the period specified (see Appendix Note B).

Annual precipitation as estimated by observation of precipitation maps for each crop-reporting district has been weighted separately by the acreages in wheat and corn. The weighted precipitations as used in this chart are as follows:

District	South Dakota		Minnesota		Nebraska		Iowa	
	Wheat	Corn	Wheat	Corn	Wheat	Corn	Wheat	Corn
West	16.1	16.6	25.2	26.1	17.1	17.1	31.5	30.5
Central	20.8	20.6	27.4	27.5	22.2	22.6	33.2	32.1
East	23.8	24.7	29.7	29.7	29.5	28.6	33.3	32.6

Effective precipitation was computed by subtracting from the annual precipitation 7 inches for South Dakota and Minnesota, and 8 inches for Nebraska and Iowa. Using 9 inches for Nebraska and Iowa might perhaps be preferable.

tive idea of the difference in the behavior of the two grains in this respect in a portion of the area covered by Charts 43 and 44. The data in the upper sections of Chart 45 were derived by dividing the average yields in crop-reporting districts by the estimated average annual precipitation. For the lower sections of the chart the average yields were divided by "effective precipitation," which was arbitrarily determined by subtracting from the average annual precipitation 8 inches in Nebraska and Iowa and 7 inches in South Dakota and the part of Minnesota included in the chart.³⁷

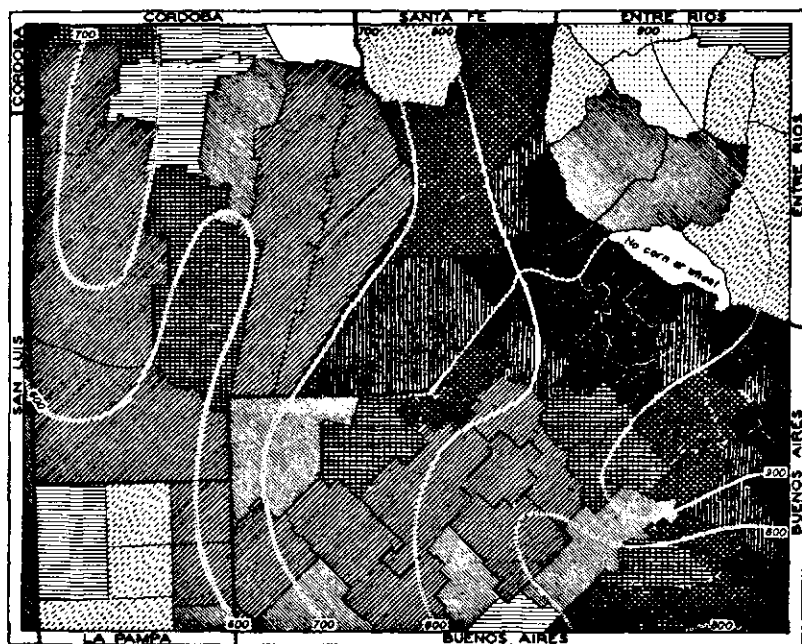
The data in Chart 45 do not yield uniform results, yet the greater efficiency of corn in utilizing additional supplies of water is well substantiated, particularly in the lower sections of the chart. While wheat yields display a tendency to decline with the increase in precipitation, even per inch of total precipitation, corn in the two northern states becomes the more efficient in yielding capacity the larger is the precipitation, even per inch of effective precipitation.³⁸

Efficiency in the use of moisture, though very important, is not the only natural factor determining the outcome of the competition between corn and wheat in the region covered by Charts 43 and 44. Obviously, corn competes more strongly with spring wheat than with winter wheat. Of particular interest is the broad and deep penetration of corn between the regions of spring and winter wheat, where the climate is too hot for spring wheat but too cold for winter wheat. This penetration, it is true, is to a great extent due also to a large proportion of soils unsuitable for wheat. The weakening of the competitive power of corn with winter wheat in the southwest,

³⁷ The number of inches was varied, so as to take account of differences in evaporation. Using 9 inches for Nebraska and Iowa might be preferable.

³⁸ A similar analysis for Kansas and Missouri reveals that the yields per effective inch of annual precipitation (9 inches subtracted to arrive at the "effective") declined with increase in total precipitation both for wheat and corn, but with the decline in wheat the much stronger one. The difference in the behavior of yields as between northerly and southerly states may be partly due to the inadequacy of the computation of effective precipitation. But, for our purposes, the changes from west to east rather than those from north to south are important, and the former persistently point to considerably better utilization of additional water by corn than by wheat.

CHART 46.—ACREAGE RATIOS REFLECTING EFFECT OF PRECIPITATION ON COMPETITION BETWEEN WHEAT AND CORN IN A PORTION OF ARGENTINA*



KEY



Annual precipitation (in millimeters)

* Official data on acreage by *partidos* in 1934-35.

owing to excessive heat which winter wheat escapes, is also clearly suggested by the charts.

Chart 46 presents the situation in Argentina in a region comparable to the portion of the United States covered in Charts 43 and 44. In Argentina, within a relatively small distance, corn falls from the position of a crop which leaves no room whatever for wheat to that of an insignificant crop secondary to wheat. Again precipitation is the most important factor, though of course not the only one. Soil conditions seem to be most important among secondary influences.

CULTURAL PRACTICES

We have seen that the five grains vary in the amounts of nutrients and water needed (chapters x and xii), as well as in their ability to make fair progress with little available moisture in the soil (chapter xii) and to extract nutrients not in readily available form (chapter x). They also differ in ability to prevent other plants from making use of supplies provided for them and to withstand acidity, alkalinity, or an excess of water; in susceptibility to diseases; and in ability to make efficient use of large supplies of water and nutrients. Hence differences must also be expected in the response of the grains to cultural practices. They are not always large, it is true, and in many cases even not readily recognizable. But in the final analysis, considerable, even fundamental shifts in relative competitive power of different grains result from the way the crops are grown. Unfortunately, limitations of space preclude a full discussion of this subject, made very complicated by the large assortment of cultural practices and the variations in response of different grains to each of them under different conditions of soil and climate and depending on the other cultural practices applied simultaneously.

The wheat plant is the weakest of the small grains in ability to extract nutrients from the soil and to prevent other plants from absorbing them.¹ It is furthermore very susceptible to disease and acidity. Hence wheat tends to rank higher than any other small grain in its response to cultural practices. But this statement is valid only for the response of the total plant rather than for the response in terms of grain produced. Since differences in the strength of the response of different grain plants to cultural practices are frequently relatively small, and since the proportion of straw to grain in the wheat plant is materially higher than in barley and oats, wheat has

¹ If not otherwise stated, comparisons of small grains always refer either to fall sowings or to spring sowings.

often to cede first rank to barley, and sometimes also to oats, in response to individual practices in terms of grain. But the inferiority of wheat diminishes as the amount of cultural practices increases, and is eventually converted into a superiority. No other grain, indeed, can be grown so intensively as wheat, i.e., is able to "consume" with advantage such large amounts of cultural practices, though winter barley comes close to winter wheat in this respect. Stiffness of the wheat straw is important in this connection, because it permits high doses of nitrogen fertilizer without lodging.

Barley is frequently the small grain with the strongest response to individual cultural practices in terms of grain. Its superiority is so large that spring barley often responds more vigorously than winter wheat. This superiority is due chiefly to the fact that barley, which like wheat needs nutrients in readily available form, has the shortest absorption period and the smallest proportion of straw to grain among the important grains. But weakness of the barley straw, and the possibility of an undesirable increase of the nitrogen content in malting barley, make it often advisable to be moderate in applying large amounts of nutrients to barley. Barley, which is not so effective as the other small grains in utilizing precipitation water in excess of the bare minimum, is not superior to wheat in response to irrigation.

Although oats are able to make fair progress under very poor conditions, they nevertheless respond readily to many cultural practices, being in some cases inferior merely to barley. Weakness of the straw is a limiting factor also with oats. Furthermore, oats do not profit so much as some other grains from irrigation, perhaps because the dry heat of irrigated regions does not agree with them.

Since rye, like oats, produces a crop under very poor conditions, and since the proportion of straw to the total weight of the plant is large, cultural practices applied to rye tend to have the smallest effect in terms of grain.

Several factors combine to place corn above the small

grains with regard to the response to many cultural practices, even though corn is rather efficient in extracting nutrients not in readily available form. The principal factor is its large yielding power. Because of this, the removal of a given obstacle by a cultural practice frequently results in surprising increase in the yield of corn. Furthermore, its slow start and wide spacing in the field make corn rather helpless against weeds if not assisted by the grower. The long period of growth during the warm season is another factor. Last but not least, corn-grain rather than corn-stover is the principal gainer from increases in total yield; no such phenomenon usually, indeed, occasionally even the opposite, is observed with regard to small grains.

When considering the responses of different grains to cultural practices, we refer to increases in yield of grain, or, if specifically stated, to increases in yield of grain and straw, in *terms of quantities*; specifically the response usually is given in absolute quantities, although percentage increases in yields also are sometimes presented, and in rare cases only these. But the decisive point economically is, of course, not the quantity but the value of the additional product. This value perforce depends partly on the prices of the different grains and their straw. From the greater importance of the increments of yield in terms of money, however, it should not be inferred that quantities should be supplanted by values in analysis of the relative responses of the different grains to cultural practices. Prices vary from place to place and from year to year. Differences in responses expressed in quantities and values must be sharply distinguished if confusion is to be avoided.

In drier regions, the response of wheat to individual practices in terms of quantities is hardly ever so much less than that of the other small grains that the difference is not over-compensated by the typically much higher prices of wheat in those regions. The only important cultural practice in which the response of wheat in drier regions may be

barely in proportion to its lower yield, or only slightly larger than that, is fallow applied in regions where wheat competes with the other grains as a spring crop, and perhaps also where fall-sown wheat competes with fall-sown barley. The response of wheat to such important cultural practices as those intended to combat weeds, irrigation, and fallow where winter wheat competes with spring barley and oats, is likely to be as large as or larger than that of the other small grains in terms of grain harvested. Corn does not profit much from fallow or thrive in the typical irrigated areas, and is not a strong competitor of wheat in drier regions anyway. Hence cultural practices by and large enhance the competitive position of wheat in drier regions, and usually do it rather substantially.

The same is true of moister regions. In moister deficit regions, it is true, the advantage that wheat commands in price is unlikely to be always sufficient to offset its disadvantage in the response to some individual practices. But the typical situation in moister deficit regions is the application not of individual practices but of a scientific combination of many practices which in toto bring the soil to a high state of fertility. To such a combination, wheat—at least the winter wheat usually grown there—responds as well as or better than any other small grain in terms of grain. Cultural practices thus tend to reinforce rather than to offset higher prices in strengthening the competition of wheat for the land. The other small grains can profit from cultural practices in this competition primarily in some specific conditions. Examples are malting barley, which is not priced less than wheat and responds more strongly to many cultural practices; rye and oats on soils which can be made usable for crops only by rather intensive cultivation but remain nevertheless unusable for the more exacting grains; and oats on soils too wet for wheat.

Even corn can seldom impair the increase in the competitive strength of wheat in moister regions resulting from the application of cultural practices, in spite of its much stronger

response to certain practices under climatic conditions favorable to it, for in these very conditions corn tends to be very much cheaper than wheat. A further factor limiting the effect of the strong response of corn to many cultural practices on world production of this grain is, moreover, that the natural conditions of the regions where cultural practices of all kinds are applied most generously are not suitable for corn.

THE WORKING OF THE SOIL

In working the soil, the farmers usually pursue several aims. The most important are: (1) regulating the soil moisture and thereby also controlling soil temperature and soil acidity; (2) giving easy access to air in order to foster chemical conversion of insoluble nutrients into a form readily accessible to plants and in order to stimulate an exuberant growth of soil bacteria; (3) changing the physical structure of the soil and subsoil to insure the roots of the plants easy access to moisture and nutrients and progressive development; and (4) preventing weeds from occupying space, consuming moisture and nutrients, or living as parasites.

The effect of the working of the soil is largely dependent upon the climate. The drier the climate, the less strongly the crop responds to the working of the soil and the less of this is needed. Applied in excess of some moderate amount where moisture is scarce, it may even bring about negative consequences.

Corn does not require a thoroughly prepared seedbed as strongly as wheat or barley; being the most prolific crop among the grains studied, it may nevertheless better reward such a preparation. On the other hand, corn is planted in widely spaced rows, and is a very slow starter; it is, therefore, most susceptible to damage from weeds and, in fact, almost fails to grow where weeds have a chance to develop.² Fortu-

² According to experiments at the Nebraska Agricultural Experiment Station covering a 6-year period, corn without cultivation yielded only 19 per cent while corn with one cultivation yielded 58 per cent as much as corn that received four cultivations. T. A. Kieselbach and others, *Cultural Practices in Corn Production* (Nebraska Agr. Exp. Sta. Bull. 293, January 1935), p. 3.

nately the same type of spacing makes after-planting operations easier and more efficient in the case of corn than with small grains. Hence, while small grains are mostly left untouched in post-seeding efforts intended to reduce the number of weeds—except in regions of very intensive agriculture—hardly any corn is grown anywhere without at least some post-seeding help against weeds. Where corn is not kept clear of weeds under current practice (three to four cultivations are usually required), it has a material reserve of competitive power. This seems to be the case in some Danubian countries, at least in backward portions of them.³

Wheat needs nutrients in readily accessible form, and it is also a slow starter. Protection against weeds is particularly important for spring wheat. It is therefore generally accepted that wheat is grateful for a thoroughly prepared seedbed and responds best to post-seeding operations where such are in vogue.⁴

Barley also needs a carefully prepared seedbed, but it (especially the six-row barley) is a quick starter and is therefore less damaged by weeds than wheat.⁵ To post-seeding operations barley responds well, though perhaps somewhat less strongly than wheat.

Oats and especially rye are modest in their requirements

³ See Otto v. Frangš, *Die sozialökonomische Struktur der jugoslawischen Landwirtschaft* (already cited), p. 32; and P. P. Egoroff, "Die Landnutzung," in *Die sozialökonomische Struktur der bulgarischen Landwirtschaft*, edited by J. St. Molloff (Berlin, 1936), pp. 105-25.

⁴ In addition to the much used light type of harrow, a specially constructed machine for cultivating small grains exists which, though not found on American farms, is in common use in western and central Europe. Information from Karl Brandt of the Food Research Institute; see also Theodor Roemer, "Bodenbearbeitung," *Handbuch der Landwirtschaft* (Berlin, 1929), II, 259-65, and F. Berkner, "Der Getreidebau" (already cited), pp. 1-108.

⁵ The importance of weeds for the competition of barley and wheat may be illustrated by the example of Carriozo Plains, San Luis Obispo County, California. In the drier and hotter portions of California wherein that county lies, fall-sown wheat yields so much less than fall-sown six-row barley that barley occupies all or most of the acreage. But in Carriozo Plains, under the protection of weed fences, wheat competes successfully with barley on only 8 inches of rainfall a year. (Personal information from Dr. F. N. Briggs and C. A. Suneson, State College, Davis, California.) The greater ability of barley to thrive on scanty moisture is generally supposed to be the reason for the present predominance of barley in California. Yet the greater ability of barley to prevent weeds from utilizing the available moisture seems also to be a factor.

for land preparation, and indeed produce sizable crops even if sown without any preparation whatever.⁵ Moreover, rye volunteers readily. Oats rank after wheat and barley in the response to post-seeding operations, while rye hardly responds at all.

ROTATION⁷

Growing crops in rotation rather than in monoculture is a cultural practice of vast import. The requirements of different crops for nutrients differ. So do the horizons of the soil from which plants extract the nutrients and water needed. Different crops need different bacteria life and suffer from different weeds, insects, and fungi. "Tiring" of the soil of a certain crop is a well-known phenomenon.⁸ Certain crops under certain conditions do not produce even half a yield if grown year after year on the same land, partly because certain insects, fungi, or bacteria have developed too abundantly, partly because certain nutrients have been exhausted. Many crops perform specific services for the benefit of crops grown in the same rotation.

The increases in yields due to rotation tend to be strong only in moister climates. In drier climates they are in general moderate, while rotational corn yields even less. The increases in yields attainable by rotation in drier climates are even more diminished if the land is fallowed every third year and practically disappear in cropping alternated with fallow.

* At Wooster, Ohio (*Handbook of Experiments in Agronomy*, already cited, p. 20), the yields of oats on corn stubble land (in bushels per acre) varied as follows with preparation of the seedbed:

No preparation—seed broadcast early and not covered..	22.3
No preparation—sown with disk drill	39.9
Land disked—sown with disk drill	56.1
Land plowed—seed broadcast and harrowed in.....	60.4
Land plowed—sown with disk drill.....	60.7

Corn stubble land, it is true, is loosened by the frequent cultivations.

⁷ The term "rotation" is used too broadly by most English-speaking people, who include in it the growing of a certain plant on the same land in alternation with fallow. The German expression "*Fruchtfolge*" covers only alternation of crops, as does the Russian word "*sevooborot*."

⁸ The German expression "*Müdigkeit*" strikingly characterizes the situation where the soil for a time cannot be used with success for some specific crop grown on it previously.

Growing more than one crop on a farm, whether on the same land or not, enables a more economical utilization of labor and capital. In many regions the advantages therefrom are even greater than those derived from rotation. As with rotation, these managerial advantages are in general more important in moister than in drier climates. Growing crops in rotation which combines the technical and managerial advantages is therefore the general practice in moister regions and is also in relatively wide use in drier regions. But continuous cropping likewise is practiced on a large scale in the latter, and none of the regions where alternate fallowing is the most profitable cropping system find it advisable to rotate their crops.

The following points seem most relevant in connection with rotation at this place: (1) the response of a given grain to different preceding crops; (2) its effect on the yield of the succeeding crops; and (3) specific services, such as a cover crop for hay. Since we do not elsewhere discuss the managerial advantages of rotations in toto, it is appropriate to consider them briefly here.

Corn.—With insufficient moisture, corn yields better in continuous cropping than in rotation. This phenomenon is brought about by the fact that the usual preceding crops of these regions (these are mostly grains) tend to exhaust all available moisture, while a material amount of this is left by corn. The adverse effects of continuous cropping, which are far less in drier than in moister climates, apparently cannot offset the beneficial effect of the better water supply. But corn does not profit much from the fact that in drier regions it does well in continuous cropping; for only principal crops are usually grown continuously, and corn in general proves profitable in drier regions only as a subsidiary crop.

While in drier climates continuous corn yields better than that grown in rotation, in moister climates the response of corn to rotation is as strong as or stronger than that of any other grain. Hay, especially legume hay, is a particularly good

crop to precede corn, and under favorable moisture conditions corn tends greatly to exceed the small grains in the response to it.⁹ Where hay is included in the rotation, corn almost always gets this privileged place after it.

Not being able to profit much in drier regions from its relatively high yields in continuous cropping as compared with rotation, corn probably also fails to gain from the fact that in moister climate rotational corn yields much better than that grown continuously. For owing to this very reason, large acreages of small grains are grown in regions with climatic conditions ideal for corn, where they would not be grown if corn could do well alone.

Beets and roots as preceding crops usually produce greater increases in the yields of small grains and other crops than does corn, but for the competition of corn with small grains it is important that corn is a better preceding crop than small grains. For example, in the cross-cropping experiment at Lafayette, Indiana (average 1922-34), oats yielded 46.6 bushels after corn and 41.7 bushels after wheat.¹⁰ On the experiment fields at Dickinson and Mandan, North Dakota, Belle Fourche and Ardmore, South Dakota, North Platte, Nebraska, and Colby and Hays, Kansas, in the rotations corn-barley-oats and corn-oats-barley, barley on the average yielded 12 per cent more after corn than after oats, while oats produced 6 per cent more after corn than after barley.¹¹

The usual explanation for the beneficial effect of corn as a preceding crop is that it leaves the land free of weeds, but in drier regions the larger amount of water in the soil after corn as compared with that after small grains is also a factor.

Since yields of small grains following corn in rotation are favorably affected by this sequence, and there are also considerable managerial advantages in alternating corn and small

⁹ The usual explanation is that the sod of hay decomposes slowly, the process being speeded up by high temperatures; and the long period of absorption of nutrients by corn, occurring mainly during the hot season, fits well with this.

¹⁰ *Soils and Crops Experiment Farm, Report of Progress, 1915-1934*, p. 11.

¹¹ For source and years, see footnote 42 of this chapter.

grains, there is undoubtedly a material enlargement of corn growing in the more humid of the drier regions, where some corn would be grown anyway, and corn occupies land in regions with moisture conditions even less favorable for it, where it might otherwise be entirely absent. In some places small grains are supposed to yield after corn not much less than after fallow; hence it is recommended to abandon this and to use the land otherwise in fallow for corn.¹² Chilcott¹³ writes of the position of corn in the Great Plains: "The importance of the corn crop is not due to its intrinsic value as a cash crop, but rather to the beneficial influence that it has upon the small-grain crops which follow it in the rotations . . ." To eliminate the fallow is a particularly vital problem for the densely populated Russia. The desire to do so is one of the most important reasons for the strenuous efforts there to introduce corn in regions where corn yields must be low owing to insufficiency of moisture.¹⁴

It is a great disadvantage of corn that it cannot be used as a cover crop to hay. The presence of hay in rotations is important owing to its favorable effects on the yields of the other crops and on long-time fertility, and there are also some managerial advantages. But farmers would seldom find it possible to include hay in their rotations if the long period of its establishment were not utilized for a small grain crop.

Wheat.—Wheat is not a particularly desirable member in rotations. An exacting crop, it does not do well after crops

¹² The role of corn as a substitute of fallow gave rise to the Russian expressions "corn fallow" and "American fallow," both meaning that the place in the rotation formerly in fallow is occupied by corn.

¹³ E. C. Chilcott, *The Relations between Crop Yields and Precipitation in the Great Plains Area. Supplement I.—Crop Rotations and Tillage Methods* (already cited), p. 11.

¹⁴ Corn as a preceding crop is even more preferable when the alternative is sorghum. This continues to grow after harvest and exhausts all moisture coming down before the first killing frost. For another reason, it is definitely recommended not to grow fall-sown small grains immediately after sorghum, unless nitrogen fertilizer is provided. See J. H. Martin and others, *Growing and Feeding Grain Sorghums* (already cited), and O. B. Mathews and L. A. Brown, *Winter Wheat and Sorghum Production in the Southern Great Plains under Limited Rainfall* (U.S. Dept. Agr. Circ. 477, July 1933).

which exhaust the soil fertility and also is particular as to soil preparation and seeding time. These requirements are not easily reconciled with the fact that, as a winter crop, wheat occupies the land for a long time. Wheat also is commonly the poorest preceding crop; at best it is among the poorest.¹⁵

The fact that wheat is not particularly desirable in rotations cannot fail to impair its competitive power. Where wheat is unable to offset the disadvantages of including it in the rotations, it is dropped. Where it is strong enough to retain a place in rotations, the effect of the behavior of wheat seems to be different in regions where the advantages of rotations are large and where they are small. Where these are sufficient as to exclude any other form of crop production—as usually is the case in moister climate—the ability of wheat to offset its disadvantages as a rotational crop cannot prevent the acreage devoted to it from being less than it would otherwise be. But where the advantages of rotations are small—as frequently is the case in drier regions—the ability of wheat to offset its poor showing as a rotational crop may be a factor contributing to the fact that a great deal of wheat is grown continuously or alternated with fallow rather than in rotation with other crops.

The extent to which wheat is undesirable in rotations obviously depends on the other crops grown in them. Changes in rotations therefore must affect its competitive strength. Only a few such changes can be discussed here.

The inclusion of hay in the rotations does not in general improve the competitive power of wheat materially, although winter wheat mostly responds to hay as a preceding crop as well as or better than any other spring-sown or winter-sown

¹⁵ No small grain, for example, proves a good preceding crop in the Great Plains, but spring wheat seems to be worst among the grains. M. A. Bell (*The Effect of Tillage Method, Crop Sequence, and Date of Seeding upon the Yield and Quality of Cereals and Other Crops Grown under Dry-Land Conditions in North-Central Montana*, already cited, p. 51) writes: "A study of the evidence as a whole would tend to favor oats over spring wheat as a preceding crop. In the section dealing with barley, it has been shown that barley was preferable to either spring wheat or oats." See also E. C. Chilcott, *op. cit.*, for extensive data at many experiment fields in the Great Plains.

small grain.¹⁶ Winter wheat is unlikely to get the place after hay in rotations where corn can be grown successfully, because this utilizes the hay sod even more effectively. Where such crops as corn compete strongly with wheat, the gain of wheat from the inclusion of hay in rotations, if any, can be only an indirect one. The state of soil fertility is increased or at least maintained by the accumulation of organic matter in the soil, while land used for legume hay must be limed if sour, since most kinds of leguminous hay are sensitive or very sensitive to acidity. Both factors favor the competition of wheat for one of the other places in the rotations with such crops as oats or rye.

In drier climates where wheat has a stronger claim on the land, the inclusion of a hay crop in the rotations does not lead to the extension of the wheat acreage and may even be accompanied by its contraction, but coarse grains often are omitted entirely. This is again true of both winter and spring wheat even though the latter hardly responds to hay as a previous crop as strongly as spring barley or spring oats. Where in moist climate hay is grown not for improving the yields of other crops but is profitable by itself, and therefore occupies a large proportion of acreage, the choice between small grains is seldom in favor of wheat. The farmer needs a feed crop there to make up a balanced diet for his livestock; oats are best for this purpose.

The competitive strength of wheat for the land is definitely increased only by including in rotations some of the crops which are most profitable if grown very intensively, especially

¹⁶ In a cross-cropping experiment at Lafayette, Indiana (*Soils and Crops Experiment Farm, Report of Progress, 1915-1934*, p. 11), the increase in yield after clover, as compared with the yield after oats, was larger for winter wheat even than for corn (6.8 centsals of wheat and 4.2 of corn). But experiments at Wooster, Ohio, showed only small increases for winter wheat after clover (*Handbook of Experiments in Agronomy*, p. 91).

As with all small grains, the extra growth of the wheat plant in response to legume hay is more strongly reflected in the yield of straw than in that of grain. In the rotation trials at Wooster (*ibid.*, pp. 91-94), the straw-grain ratio (grain = 100) for winter wheat was as follows:

After clover	178	After soybeans	151
After corn	161	After oats	165
After potatoes	155		

if these crops, such as sugar beets, do best in slightly alkaline to slightly acid soil. Successful growing of sugar beets precludes their frequent return to the same land because nematodes overinfest the soil. Sugar beets also usually involve two sharp labor peaks in spring and in fall. In Europe it is therefore not considered good practice to have them oftener than once every four or perhaps every three years. Part of the free space in the rotation has to be occupied by small grains. Since wheat yields relatively better than the other small grains on the highly fertile, clean, slightly alkaline or only slightly acid "beet" land, wheat is rather regularly used to succeed sugar beets.¹⁷

Other grains.—Oats are the reverse of wheat in their role in rotations. They are extensively grown, not for their own sake as a principal crop, but as a subsidiary crop which fits well in the rotations with other crops. Oats produce good crops if located in good places in rotations, but, being modest in their requirements as to soil and its preparation, they also yield relatively well in the poorest places. In Germany oats are called *die abtragende Frucht*, meaning the crop which cleans off the residuals of nutrients that remain after more exacting crops. Further, oats are a favorite crop for places in rotations in which no sufficient time or labor and power are available for preparing the land for the small grain crop; this contributes to the strength of oats in the Corn Belt.

As a preceding crop, oats are better than wheat and in moister climate not worse or perhaps better than barley. There are some variations in the requirements as to a cover crop for hay, but for this in many regions oats are as good as or better than any other spring grain.¹⁸

The use of oats in rotations as a convenient subsidiary crop is, however, substantially limited to moister climates. In

¹⁷ Potatoes, which also readily repay very intensive cultivation, prefer moderately acid soils and favor oats and rye as their rotational companion, or at least do not disfavor them.

¹⁸ Winter grain is somewhat less adapted to this purpose; winter rye seems to be least desirable.

drier climates barley plays this role more effectively. Being the earliest maturing crop, it helps to keep down later maturing weeds. The service of barley in combating weeds is especially valuable in regions specializing in spring wheat. In these it presents also greater managerial advantages. In the hard-spring-wheat regions of the United States and Canada, in fact, barley is quite regularly introduced when continuous spring wheat tends to be overcome by weeds.

Since rye is as modest as oats in its requirements as to soil and its preparation, it also is to some extent used in poorer places of rotations or in places where a crop cannot be given much attention. But rye, generally grown as a winter crop, occupies the land much longer than oats, commonly grown as a summer crop. A fall-sown crop may sometimes be specifically desired for certain reasons, but these opportunities are much rarer than where a spring grain is preferred. Where either grain can be conveniently sown, the adverse attitude of feeders toward the use of rye becomes a particularly strong factor. Except on farms with little livestock other than hogs, rye is unlikely to get the choice.

Rye as a preceding crop has an advantage over wheat in being stronger as a weed-combater. But this advantage may be offset by the fact that rye volunteers freely.

MANURE¹⁹ AND COMMERCIAL FERTILIZER

In discussing the working of the soil and rotation, distinction had to be made between the responses of the grains in moister and drier climates respectively. Such distinction is even more pertinent with regard to applications of nutrients. This is because in drier climates the limiting factor is mostly moisture rather than nutrients. A large supply of nutrients in readily available form may even reduce the yield of grain by stimulating excessive growth of the plant and a correspondingly large consumption of moisture in the early stages of its growth. A large supply of nitrogen in any form (a legume as

¹⁹ Whether stated specifically or not, manure always means barnyard manure.

a preceding crop, manure, or commercial fertilizer) is the nutrient which is likely to cause this growth.

There is ample evidence to support those statements. For example, at the experiment station in north central Montana (average annual precipitation 11.87 inches), such large applications as 10 tons of barnyard manure per acre to spring wheat, spring oats, and corn failed entirely, both on fallowed and stubble land, except for an increase in the amount of corn stover.²⁰ At Colby in northwestern Kansas, winter wheat failed to respond to manure applied in different forms, although the average annual precipitation was 18.02 inches.²¹

Even where responses to manure are attained—much more moisture is usually necessary for this than is available at the Montana north central station—they mostly are largely insufficient to make the application a paying proposition. At Brookings, South Dakota (average annual precipitation 19.7 inches), in a rotation corn-oats-wheat-legume, an application of 10 tons of manure once in four years produced an increase in the grain yield of the three grain plants of only 11.2 per cent on a 25-year average, while the percentage increase in yield of straw and stover was almost twice as large.²² Even the increase in yields of the size obtained at Manhattan, Kansas, which receives much more moisture (average annual precipitation 31.84 inches),²³ frequently is not enough to repay the application, especially as drier regions tend to have low grain prices.

Manure in drier regions is profitable, if at all, only on poorer soils and/or in regions relatively better provided with water; and even this is possibly more as a means of keeping up long-time fertility than because of current increases in yields. Application of complete fertilizer is unlikely to be

²⁰ Average for 10 to 18 years. M. A. Bell, *The Effect of Tillage Method*, pp. 56-57.

²¹ J. B. Kuska, *Methods of Crop Production at the Colby (Kans.) Branch Experiment Station, 1915 to 1929* (U.S. Dept. Agr. Circ. 184, September 1931), p. 22.

²² J. G. Hutton, *Thirty Years of Soil Fertility Investigations in South Dakota* (South Dakota Agr. Exp. Sta. Bull. 325, June 1938), p. 33.

²³ R. I. Throckmorton and F. L. Duley, *Twenty Years of Soil Fertility Investigations* (already cited), pp. 16-23.

profitable in any drier region except perhaps in some of those where grain prices are kept high by protectionist measures. Applications of certain specific minerals to soils definitely deficient in them is more likely to produce paying results; but thus far only application of phosphates—and these only in Australia—has become of large practical importance.

Since applications of manure and commercial fertilizer in drier regions are of little significance, the same is true of the differences in response among the grains. Corn is likely to make the worst showing with regard to the response to application of nitrogen in any form, except where it is grown to be cut green. Winter wheat may be supposed to show a relatively better response than spring-sown six-row barleys, usually grown in drier regions, and spring oats, while fall-sown wheat is likely to respond at least as strongly in terms of percentages as fall-sown barley. Since, moreover, wheat tends to be much higher-priced in drier regions than barley or oats, application of manure and/or commercial fertilizer, so far as it is profitable, in no case can detract from its competitive power and in general materially increases it.

With the response to applications of nutrients in drier regions generally absent or insufficient to repay the cost, it is only natural that almost all barnyard and green manure, legume hay, and commercial fertilizer (the amounts and significance of which were briefly discussed in the section on "Long-Time Fertility" in chapter x) are applied or grown where crops get sufficient moisture. Soils formerly in forests are in fact the natural recipients of applied fertility, both because they are largely or entirely deprived of it by leaching and because deficiency of moisture cannot prevent its utilization by the plants.²⁴

²⁴ The same is true of lime, because only soils getting much water from precipitation tend to be too acid. Lime, though of immense importance for the competition among grains, hardly needs more than a few remarks. The response to lime is in general the stronger, the greater the sensitiveness of the grain toward acidity. Many lands entirely unsuitable to wheat and barley have been converted into good wheat or barley land by liming. If, in rotations of the type legume-corn-wheat, corn sometimes responds to liming more strongly than wheat, this is brought about by the fact that many legumes are very sensitive to acidity, and corn following the legume on limed land profits much from the improvement of the legume.

Corn.—There is hardly any doubt that under climatic conditions favorable for corn this grain considerably exceeds the small grains in the response to manure, commercial nitrogen, and, to a lesser extent, minerals, particularly if a deficiency in a certain nutrient prevents corn from exerting its huge growing power. But in response to complete commercial fertilizer corn is hardly much superior to winter wheat.

Experiments covering 40 years at State College, Pennsylvania, in a 4-year rotation of corn-oats-winter wheat-mixed clover and timothy hay, with manure applied to corn and wheat, showed an increase in the yield of corn of 15 centals per acre as against only 6.6 centals of winter wheat.²⁵ In Wooster, Ohio, 2.5 and 5 tons of manure applied in continuous cropping produced increases of 13.4 and 19.0 centals of corn as against 8.5 and 11.3 centals of winter wheat, respectively.²⁶ Data in Table 13 show that at Wooster, Ohio, corn responded to 160 pounds of nitrate of soda with an extra yield of 3.12 centals, while only 1.13 centals of winter wheat were obtained. But 420 pounds of complete fertilizer to winter wheat were reflected in nearly as large an increase in yield as that produced by the application of 320 pounds to corn.

The much stronger response of corn to manure and commercial nitrogen, as well as to legume hay, already discussed in the preceding section, is primarily due to the fact that additional growth of corn goes in about equal proportion into grain and stover, while small grains tend to produce much straw under these conditions. The following additional amounts of straw or stover were produced on manured plots for each 100 pounds of added grain:²⁷

Grain	State College, Pennsylvania	Purdue Farm, Indiana
Corn	86	114
Oats	245	138
Winter wheat	220	202

²⁵ C. F. Noll and others, *Fiftieth Anniversary of the General Fertility Tests, 1881-1931* (already cited under Table 7), p. 7.

²⁶ C. E. Thorne, *The Maintenance of Soil Fertility* (already cited under Table 7), pp. 296-98.

²⁷ Data from Table 7, p. 208. Stover includes cobs.

TABLE 13.—RESPONSE TO COMMERCIAL FERTILIZER OF CORN, OATS, AND WINTER WHEAT IN A ROTATION CORN-OATS-WHEAT-CLOVER-TIMOTHY AT WOOSTER, OHIO, AVERAGE OF 1894-1923*

Fertilizer	Application (Pounds per acre)		Increase in yield (Centals per acre)		
	On corn and oats	On wheat	Corn	Spring oats	Winter wheat
Nitrate of soda.....	160	160	3.12	1.53	1.13
Superphosphate.....	80	160	4.33	3.07	4.54
Muriate of potash.....	80	100	3.07	1.20	0.49
Complete fertilizer* ...	320	420	11.60	6.66	10.06

* C. E. Thorne, *The Maintenance of Soil Fertility* (already cited under Table 7), pp. 301, 305, 309. Data of the east field have been used. A similar table based on earlier data is presented in W. W. Weir, *Soil Science. Its Principles and Practice* (Chicago and Philadelphia, 1936), p. 447.

* In the proportions shown above.

Wheat.—Evidence on the ranking of small grains according to the response to manure and commercial fertilizer varies. Experiments at the Dominion Station, Ottawa, show oats responding to manure more strongly than spring wheat.²⁸ The Rothamsted experiments²⁹ indicate that spring barley even surpasses winter wheat, although winter grain is in general superior to spring grain. But according to Prjanischnikow,³⁰ winter wheat excels all other small grains. The differences between the responses of small grains to manure are not very important, it is true, because these rarely have direct access to manure except on poor soils growing little but rye and oats.

Russell³¹ summarizes the experience with the use of commercial nitrogen in England: "Wheat is seen to be less efficient as a user of nitrogen than barley or oats in English conditions." The pertinent data show the following increases

²⁸ C. E. Thorne, *Farm Manures* (New York, 1913), p. 189.

²⁹ *Report for 1935* (Rothamsted Experiment Station, St. Albans, 1936), p. 157.

³⁰ D. N. Prjanischnikow, *The Field Crops* (already cited), p. 107.

³¹ E. J. Russell, *Artificial Fertilizers in Modern Agriculture* (Great Britain Ministry of Agriculture and Fisheries Bull. 28, 1933), pp. 18-19.

in yields, in centals, that can be expected per hundredweight of sulphate of ammonia:³²

Crop	Grain	Straw	Total
Barley	3.38	7.00	10.38
Oats	2.94	6.72	9.66
Winter wheat ..	2.70	5.60	8.30

Thus the response even of the whole plant of winter wheat to nitrogen is less than that of spring barley and spring oats. But according to some other data, there is no difference between winter wheat and spring barley, and winter wheat is superior to oats. German data by Schneidewind,³³ Heuser,³⁴ and others leave no doubt that winter wheat is superior to rye in the response to applications of nitrogen, especially if the applications are large.

According to Morgan,³⁵ responses of oats "to phosphorus and potassium are usually less definite than for either corn or wheat," but in this respect too European data are less favorable for wheat.

It is of immense importance for the competition of wheat for the land that in the response to complete fertilizer winter wheat tends to be superior to all other grains, save corn in climatic conditions especially favorable for the latter. Winter wheat makes an especially favorable showing if application of complete fertilizer is accompanied by a plentiful supply of manure and/or rotational legume, i.e., if the soil is brought to a very high state of fertility. In the general fertility test at Dikopshof, Bonn-Poppelsdorf, Germany (in the rotation of sugar beets—winter wheat—winter rye—oats), winter wheat yielded 26.2 and 29.8 per cent less than winter rye and oats, respectively, on untreated plots, while 10.3 and 3.2 per cent more winter wheat, respectively, was produced on

³² E. J. Russell, *Artificial Fertilizers in Modern Agriculture*, p. 19. Russell's rounded figures lose this character in conversion into centals.

³³ Wilhelm Schneidewind, *Die Ernährung der landwirtschaftlichen Kulturpflanzen* (Berlin, 1915).

³⁴ W. Heuser, "Wintergetreideversuche in Ostdeutschland" (already cited), p. 356.

³⁵ M. F. Morgan and others, "The Soil Requirements of Economic Plants" (already cited), p. 758.

plots treated with lime, manure, and complete commercial fertilizer.³⁶ Paradoxically, so far as concerns response to abundant fertilizer, wheat is the grain best adapted to the very intensive agriculture of western and central Europe.

Barley, oats, and rye.—The very favorable showing of barley in response to applied nutrients, as demonstrated above, pertains primarily to spring-sown two-row barleys almost exclusively grown in the intensive agriculture of western and central Europe. The findings may not always entirely apply to the more robust six-row barleys predominantly grown outside of that region. But most manure and commercial fertilizer is applied in regions where two-row barleys are grown. These undoubtedly profit to some extent from their strong response to application of nutrients. Lime and applied nutrients, for example, contribute much to the fact that every country easily covers its need for malting barley.³⁷ The large danger of lodging and apprehension over the protein content of the malting barley are important limiting factors in the use of large quantities of applied fertility to barley. According to Watson and More,³⁸ the best malting barley is grown on land from which any excess of fertility has been removed by a preceding small-grain crop.

The relatively small responses of spring oats to manure and commercial fertilizer shown by many experiments in the United States (see Table 13, for example) may be due to the fact that the climate in general is too hot for the best yields of spring oats. In cooler climates their response, although not always stronger than that of winter wheat and often weaker than that of spring barley, is sufficiently strong to enable oats to remain a strong competitor in the very regions where the highest

³⁶ A. Richardsen, "Der statische Versuch in der Versuchswirtschaft Dikopshof an der Landwirtschaftlichen Hochschule Bonn-Poppelsdorf," *Landwirtschaftliche Jahrbücher*, 1933, LXXVII, 157-206. Manure was applied to sugar beets and rye. Oats received half as much commercial nitrogen as wheat and rye, but the same amounts of P_2O_5 and K_2O .

³⁷ Except for some "sunshine barley" in Great Britain; but by hastening maturity, phosphatic fertilizer even replaces the sun to some extent.

³⁸ J. A. S. Watson and J. A. More, *Agriculture; The Science and Practice of British Farming* (already cited), p. 179.

yields of all crops are obtained by intensive methods of crop production. The substantial shortening of the growing period attained by the application of phosphoric acid proves an important asset of oats in preserving their place in the moist climate of northwestern and north central Europe. Weakness of the straw is an impediment to large applications of nutrients also in the case of oats.

Winter rye is inferior to all other grains—whether sown in the fall or in the spring—in the response to all kinds of applied fertility, especially if the applications are large. It profits from application of nutrients only where the lightest soils, unusable for the more exacting crops even with the amplest applications, are involved. Spring rye is even weaker in its response. Experiments described by Heuser³⁹ leave no doubt that spring rye does not fit into intensive agriculture.

FALLOW⁴⁰

In drier regions with soil of a large water-holding capacity, it frequently proves more profitable to produce one crop from the precipitation of two years. In moister regions, fallow is to some extent resorted to only where the soil is poor and the methods of crop growing extensive, especially in regions with a short growing season and small manure production.⁴¹

³⁹ W. Heuser, "Bericht über dreijährige Sommergetreidearten-Versuche in Ostdeutschland," *Landwirtschaftliche Jahrbücher*, 1933, LXXVII, 247-51.

⁴⁰ In hot climates where two crops in one year are possible, the omission of one of them is frequently referred to as fallow. In the text, the term fallow applies only to arable land which is not used for crops during a whole year.

⁴¹ An idea of the extent of fallow in the most important countries of the world is given in the following tabulation, in million acres:

Country or subdivision	Year	Total acreage in crops	Fallow
Prairie Provinces	1937	25.5	14.8
Oregon	1929	3.0	1.2*
Washington	1929	3.8	2.4*
California	1929	6.8	1.5*
Australia	1935-36	19.6	9.8
Algeria	1935-36	8.5	6.4
Tunis	1935	3.4	3.9
Morocco	1936	9.7	7.8
USSR	1934	324.9	228.4*

* Fallow includes idle crop land for the United States and for the USSR. The amount of idle land in California is rather large. Fallow in the USSR amounted to 64.9 million acres in 1934.

Data for Canada from Dominion Bureau of Statistics, *Monthly Bulletin of Agricul-*

The following tabulation shows the increases in yields attained by cropping alternated with fallow, as compared with continuous cropping, on experiment fields in the Great Plains:⁴²

State	Winter wheat	Spring wheat	Spring barley	Spring oats	Corn
INCREASE IN CENTS PER ACRE					
Montana	6.1	3.3	5.0	4.5	...
North Dakota .....	...	3.7	4.2	5.6	1.3
South Dakota, Nebraska, Kansas, Wyoming	5.9	3.9	5.9	3.8	2.9
INCREASE IN PERCENTAGES					
Montana	158	60	87	61	..
North Dakota .....	..	54	69	72	..
South Dakota, Nebraska, Kansas, Wyoming	96	70	74	56	38

Thus winter wheat is far superior to spring wheat in the response to fallow. The behavior of other fall-sown grains is similar because, due to lower temperatures during the growing season, fall-sown grain utilizes the stored moisture more economically than grain sown in the spring. Owing to the stronger response of fall-sown grain to fallow, as well as to managerial advantages, the fall-sown grain is usually placed after fallow in rotations consisting of fall-sown grain, spring-sown grain, and fallow.⁴³

tural Statistics, March 1938, XXXI, 109; for the United States from the Bureau of the Census; other from *International Yearbook of Agricultural Statistics, 1937-38*. Total acreage in crops and fallow pertains to all crops rather than to grain only. But fallow is widely practiced only in regions where no crops other than small grains are grown in substantial quantities. The ratio of fallowed to the total land in crops in these regions, therefore, is considerably higher than for the country or state as a whole. For example, only about 40 per cent of the barley and wheat crop in California is grown on land which is not fallowed. Polish statistics indicate for 1937 3.4 million acres in fallow as against 42.4 million acres in crops, but the figure for fallow seems to be too small.

⁴² Data for Williston, Assiniboine, Moccasin, Huntley, Edgeley, Sheridan, Scotts Bluff, Archer, and Akron from E. C. Chilcott, *op. cit.*, *Supplement 1*, pp. 44-63. Data for Dickinson, Mandan, Belle Fourche, Ardmore, North Platte, Colby, and Hays from the same source brought up to date in the Division of Dry-Land Agriculture, U.S. Department of Agriculture. Thanks are due to J. S. Cole, Senior Agronomist of that Division.

⁴³ Exceptions occur if the spring grain greatly exceeds the winter grain in profitability and/or if there are some specific objections to having a certain fall-sown grain before the spring-sown grain in the rotation. In North America's hard-spring-wheat regions, for example, winter rye is not favored to precede spring wheat owing to the danger of volunteer rye appearing in the spring wheat.

The response of winter wheat to fallow exceeds that of winter rye, according to Prjanischnikow,⁴⁴ probably both in percentages and cents. It is also rather doubtful whether fall-sown oats grown on fallow would produce more extra grain than fall-sown wheat so grown.

Corn is inferior to all spring-sown small grains in the response to fallow, because it is sown later and its growing period includes the hottest time of the year, and also because continuous corn leaves more moisture in the soil than small grains and hence less gain in moisture storage is secured by fallowing.

The data in the tabulation, showing that spring wheat responds about as strongly to fallow as spring barley and spring oats in terms of percentages but materially less in terms of cents, should probably not be accepted as conclusive. Both spring barley and spring oats, it is true, can produce more grain from a given quantity of water than spring wheat, but the weed-clearing effect of fallow is less important for them. Barley and oats are also likely to suffer more from lodging, which is more frequent on fallowed than on stubble land. The data in the tabulation can be safely used only as proof that spring wheat does not gain more than spring barley and oats in terms of quantities.

Thus where wheat can be grown only as a spring crop, its competitive relation to barley and oats is not diminished by fallow and may even be increased.⁴⁵ Such an increase can positively be expected, and a considerable one at that, where fallow is profitable and winter wheat but no winter barley can be grown.

Under such conditions, hardly any grain other than winter wheat is grown on fallow in drier regions adapted to winter wheat but not to winter barley. The same is true of spring wheat in the hard-spring-wheat regions of the United States and Canada. But in the Russian spring-wheat belt they fre-

⁴⁴ D. N. Prjanischnikow, *The Field Crops*, p. 71.

⁴⁵ No information unfortunately seems to be available on the response to fallow of winter rye in comparison with that of spring wheat.

quently grow winter rye on fallow, considering it an indispensable crop to precede durum wheat. In drier regions suitable for fall-sown barley, this grain is grown on fallow almost as frequently as wheat, proportionately. Much winter rye is grown on fallow, on soils unadapted to wheat, in central and northern Russia and adjacent countries.

IRRIGATION⁴⁶

Irrigation is used primarily for crops other than grains; for grain is not so valuable as cotton, for example, and is not so efficient in utilizing much water as beets, potatoes, or alfalfa, for example. Rice, of course, is a pertinent exception. Although grains other than rice are grown under irrigation in many countries, only a few have irrigated acreages of these grains of such proportions as to be of much international significance. Of these, British India is by far the most important one, with 17.2 million acres in irrigated wheat, barley, corn, and millets in 1934-35. Egypt had 3.7 million acres in irrigated wheat, barley, corn, and sorghum in 1936, and Spain slightly more than a million acres of irrigated land in all grain in 1935. Little more than one per cent of the grain acreage was irrigated in the United States in 1929; of the 2.5 million acres in irrigated grains other than rice, 267,000 were in winter wheat, 732,000 in spring wheat, 477,000 in corn, 422,000 in oats, 666,000 in barley, 110,000 in sorghum, and 12,000 acres were in rye.

Irrigated lands on which the grains studied here are grown are mostly originally dry, or at least the season when they are grown is dry. (It is usually otherwise with rice.) The growing conditions under such irrigation display substantial peculiarities as compared with those encountered by plants where abundant moisture is provided by precipitation. Water is ample, yet the air is dry and there is plenty of sunshine

⁴⁶ Thanks are due to C. S. Scofield, Principal Agronomist, Division of Western Irrigation, U.S. Department of Agriculture, and to Professor D. W. Robertson, Colorado State College, for reading an earlier draft of this subsection and making useful suggestions.

and little, if any, acidity of soil. Many irrigated lands even tend to become alkaline. Consequently some departures may be expected in the behavior of different grains from that observed under precipitation. The evidence, unfortunately, is insufficient and partly contradictory.

As under ample precipitation, the superiority of fall-sown over spring-sown grain is only moderate under irrigation, provided summer temperatures are not too high. The moderate additional yield of winter wheat over spring wheat under irrigation⁴⁷ brings it about that irrigation farmers, in regions of the United States having a short frost-free period, find it frequently advisable to grow spring wheat rather than winter wheat which interferes with the crops that are particularly important in irrigated farming of those regions.

At Prosser, Washington (elevation 800 feet), spring wheat outyields both spring barley and spring oats persistently and heavily under irrigation; Jenkin, a spring wheat, in 1922-37 averaged 29.57 cents per acre as against 24.43 and 24.79 cents for Markton oats and Blue barley, respectively.⁴⁸ The situation at Prosser is obviously an exception, Jenkin being moreover a variety of club wheat, which is rarely grown outside the Pacific states. There is little doubt, however, that yields of wheat are more impaired than those of barley, its main competitor in irrigated areas, by a small supply of moisture. In spite of the less favorable proportion of grain to straw in the wheat plant, wheat and barley may probably be expected to show equal increases in yield in terms of grain, under ample irrigation, over yields obtainable on the same land with small amounts of moisture, and occasionally the additional yield of wheat grain may even be the larger one.⁴⁹

⁴⁷ Unfortunately we do not have sufficient data to support this statement.

⁴⁸ Personal information from H. P. Singleton, superintendent of the branch station at Prosser.

⁴⁹ This supposition is supported by data for Montana. See S. E. Johnson, *An Economic Analysis of Production Problems on the Flathead Irrigation Project* (Montana Agr. Exp. Sta. Bull. 237, December 1930), p. 59; and P. L. Slagsvold and Clyde Howard, *Production Requirements and Costs on Irrigated Farms in Montana* (Montana Agr. Exp. Sta. Bull. 338, April 1937), p. 7. Personal information from Professor R. L. Adams,

Most irrigated areas, moreover, belong to those where wheat is much more expensive than barley. Irrigation therefore strengthens the predominant position that wheat commonly has in drier regions. In Egypt, where all crops are irrigated, the wheat acreage is more than five times as large as that of barley, while barley occupies the larger area in the driest portions of northern Africa relying on precipitation. In British India, the irrigated area in wheat also is more than four times as large as that in barley. In fact, much more wheat is irrigated in the world than all other grains, except rice, combined.

Many experiments with irrigated grain growing in this country have included oats but not barley. It was probably expected that oats, the water-loving grain, rather than barley, the grain of dry climates, would be the more appropriate of the two under irrigation. But the hot air, usual in irrigated areas, is less harmful to barley than to oats. Oats also probably thrive best in moderately acid soil, while irrigated lands of the type involved tend to alkalinity. What little data are available support these views.⁵⁰ Indeed, in no part of the world have oats established themselves on irrigated land.

The situation with corn resembles to some extent that with oats. Corn to yield heavily needs moisture not only in the soil but also in the air. The data most favorable for irrigated corn which have come to the attention of the writer are those

University of California, on yields in California, and comparisons of average yields in Egypt by districts, point in the same direction.

The responses of wheat relative to those of barley sown in the same season seem to be stronger under irrigation, according to these data, than the responses to fallow according to the data discussed in the preceding section. The explanation may be that irrigation permits growing later-maturing varieties, and that wheat perhaps gains more from this opportunity than barley.

⁵⁰ P. L. Slagsvold and Clyde Howard, *op. cit.*, assume for Montana irrigated lands—perhaps a little too optimistically—a yield of barley exceeding that of oats by 35 per cent. At Fort Collins and Fort Lewis, Colorado (D. W. Robertson and others, *Oat Production in Colorado, 1928-35*, Colorado Agr. Exp. Sta. Bull. 430, July 1936, and *Barley Production in Colorado, 1298-35*, Colorado Agr. Exp. Sta. Bull. 431, August 1936), Trebi barley outyielded Markton oats by 23 and 17 per cent, respectively. Fall-sown barley outyields fall-sown oats at the Salt River Experiment Station in Arizona, but in the more moderate temperatures of Prosser, Washington, the yields of spring barley and spring oats are equal.

for the experiment field at Scotts Bluff, western Nebraska (elevation approximately 4,000 feet), where continuous corn outyielded continuous oats by only 31 per cent, on the average of 1926-34.⁵¹

The higher the temperatures, the less can corn profit from irrigation. It proves, therefore, particularly weak where the climate is sufficiently warm for sorghum. "The sorghums are . . . more important than corn in the hot but irrigated Salt River and Yuma districts in Arizona," according to Baker.⁵² Grain sorghum is furthermore preferably grown on irrigated land in California, in spite of the much higher prices of corn.

Some rather exceptional concurrence of favorable factors is needed to give corn a very strong claim on irrigated land. In Egypt, corn is the leading grain crop, with an acreage somewhat larger than that in wheat, while the acreage in sorghum is slightly more than one-fourth that of corn. Though climatically adapted to the whole country, sorghum does not become important before Upper Egypt is reached. Cotton, Egypt's chief crop, cannot be grown in rotation with wheat or barley (on the same land and in the same year), while corn is well suited to this purpose. Moreover, in the fall and early portion of the cold season, when the land is free from cotton, climatic conditions seem to be reasonably adapted to corn growing but not to sorghum. It is not too hot and also not too cold, and the air is not very dry. Similar reasons apparently explain why relatively more corn than sorghum (*jowar*) is irrigated in British India.⁵³

⁵¹ S. H. Hastings, *Irrigated Crop Rotations in Western Nebraska, 1912-34* (U.S. Dept. Agr. Tech. Bull. 512, May 1936), pp. 9, 14. Corn made a better showing in some of the rotations, but in no case was the relative yield of corn as favorable as in the heart of the Corn Belt.

⁵² O. E. Baker, "Agricultural Regions of North America: Part X—The Grazing and Irrigated Crops Region (continued)" (already cited), p. 353.

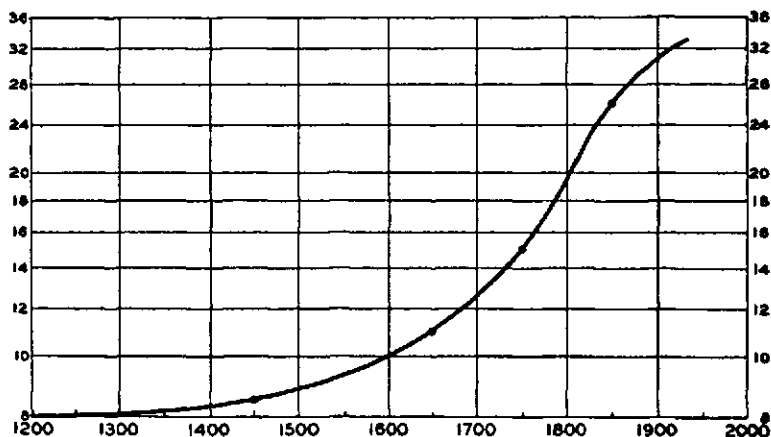
⁵³ In 1934-35, 6 per cent of jowar and 16 per cent of corn were irrigated, but the irrigated area in jowar exceeded that of corn by 31 per cent.

CHAPTER XIV

HISTORICAL DEVELOPMENTS AFFECTING GRAIN YIELDS

The average yield of wheat in Great Britain is now about 35 bushels per acre. "Down to the beginning of the sixteenth century, a yield of 8–10 bushels per acre of wheat was considered a normal crop."¹ Chart 47 shows how Bennett imagines the trend of wheat yield in Britain. The quadrupling of the average yield in four centuries tells the story of the

CHART 47.—GENERALIZED TREND OF BRITISH WHEAT YIELDS FOR SEVEN CENTURIES, ACCORDING TO BENNETT*



* Reproduced in part from M. K. Bennett, "British Wheat Yield per Acre for Seven Centuries," *Economic History* (supplement to *The Economic Journal*), February 1935, III, 27. Figures are in bushels per acre, plotted on a logarithmic vertical scale.

enormous achievement of men in crop growing. Not only have they learned to produce grain with only a fraction of the effort previously expended, but they have been freed from the necessity of limiting production to grains which are ex-

¹ John Percival, *Wheat in Great Britain* (Leighton, Shinfield, Reading, Berks, Eng., 1934), p. 40.

tremely modest in their growing requirements. The competitive power of the more exacting grains, especially of wheat, has been greatly augmented during the past four centuries. Recognition of the great importance of manure and lime, and of creating a deeper layer of topsoil by deep plowing and by breeding an abundance of active soil bacteria; the introduction of rotations intended to enrich the soil with nitrogen, and later of commercial fertilizer; the spectacular development of agricultural machinery, seed breeding, plant pathology, drainage, irrigation—these and many other factors have combined to bring about these results.

The beneficial effect of such materials as wood ashes, bone meal, and guano on fertility of the soil had been recognized before Christ. Knowledge of the favorable effects of legumes on the yields of the succeeding crops is as old as ancient Rome. The use of manure is several centuries old, while commercial nitrogen has been used in England since 1650. But little occurred in the Occidental world to increase soil fertility on a large scale before the beginning of the nineteenth century, and many developments are even more recent.²

The properties of manure may have been known for a long time; but heavy application of it could not begin so long as the diet was almost exclusively vegetarian, and the shift to the consumption of large amounts of animal food by broad masses of consumers got under way only after the beginning of the nineteenth century. Widespread growing of legumes on a large scale, at least in the Occident, was also a comparatively late development; it likewise was greatly hampered by the small requirement for hay before the industrialization era. The fertilizer industry is less than one hundred years old, and did not attain very large dimensions before the turn of the present century. World consumption of commercial nitrogen was less than 100,000 metric tons in 1885 and less than 250,000 in 1900,³ as against estimated present utilization in

² *Handbuch der gesamten Landwirtschaft*, published by Karl Steinbrück, I. *Betriebslehre* (4th ed., Leipzig, 1923).

³ Wilhelm Schneidewind, *Die Ernährung der landwirtschaftlichen Kulturpflanzen* (already cited), p. 265.

agriculture of over 2,000,000 metric tons. World production of superphosphate increased from 1.5 million short tons on the average of 1881-85 to 5.9 million on the average of 1901-05, and to 17.2 million short tons in 1936.⁴ Moreover, prices of commercial fertilizer were long so high that it was used in only a few countries and on only a few crops—as on sugar beets, which respond strongly to fertilizer and have also been highly subsidized in many countries. Nitrogen, the most expensive of commercial fertilizers, has come within reach of the cheaper crops in many countries only in the last two decades, with the phenomenal development of the production of synthetic nitrates. Yet the use of large amounts of commercial fertilizer on the less responsive crops still remains unprofitable even in many deficit countries and regions, while hardly any surplus region can use large quantities of them for such crops unless the specific crop is subsidized in one way or another; and even small amounts are used only exceptionally.

The development of modern agricultural machinery falls entirely in the nineteenth and twentieth centuries. In the beginning of the nineteenth the farmers of even the most progressive regions had nothing but the wooden plow for working the soil. In much of the world farmers used instead an implement—also primarily of wood—that resembled the present duck-foot. It did not turn the land but scratched it a few inches deep. In another part of the world no machinery drawn by animals was used at all, all land preparation being by hand, with the help of the hoe. The steel plow was not developed before the 1870's, after small numbers of the less efficient cast-iron and similar plows had been used for some decades. The other implements for working the land are of still later date.

Machinery for harvesting small grains other than the scythe and sickle is just about one hundred years old, even if the count starts from the earliest beginnings. The twine

⁴ *The Fertilizer Review*, January-February 1939, XIV, 15. The figures for superphosphate are for the total weight, those for nitrogen for plant food only.

binder and combine were not developed before 1880. The modern small combine with an auxiliary motor was introduced east of the Rocky Mountains only in the 1920's.⁵ Harvesting machinery for corn is even more recent than that for small grains.

Breeding is as recent as the other most recent developments. Among the factors studied, irrigation is the only exception in that it was known and practiced a thousand years ago. But irrigation too has been greatly extended in the last three or four centuries and especially in the past century.

All in all, incomparably more toil had to be expended a few centuries ago on an acre of any grain than is needed now. But the difficulties encountered in growing the more exacting grains were particularly prominent then. With the knowledge and technique of those days, production of wheat, the most exacting grain, was simply impossible in the civilized world, then practically limited to northwestern and north central Europe, except in particularly favored places. Hence the competitive power of wheat has increased vastly owing to the development of modern agricultural technique.

Specifically, wheat gained most from the widespread use of barnyard manure. Manure permits wheat production on soils which are otherwise unsuitable. It does this both in an immediate way, by providing nutrients in readily accessible form for the current crops, and in a slow way, by bringing about a permanent increase in the humus content of the soil. In the long run, the slow way may be the more important in promoting wheat production. Where large amounts of organic matter are continuously applied to the land, the humus content is slowly increased. Light soils become heavier and finally reach the form permitting wheat growing. (Barley growing is made possible at an earlier stage.) The final effect of manure on very heavy soils is similar: they become lighter

⁵In presenting the development of farm machinery the writer largely follows Leo Rogin, *The Introduction of Farm Machinery in Its Relation to the Productivity of Labor in the Agriculture of the United States during the Nineteenth Century* (Berkeley, Calif., 1931).

and thus lose the properties which made them rather unsuitable for wheat. Moreover, manure is almost indispensable in intensive agriculture in general, especially in the production of roots and tubers; roots in their turn substantially enlarge the competitive power of wheat.

The importance of commercial fertilizer in strengthening the competitive power of wheat has been sufficiently demonstrated on pages 325-26. Wheat responds more strongly than rye, its most important competitor in many regions, to commercial fertilizer (in terms of grain yield), and in certain cases it is also superior in this respect to some other grains. The higher value of wheat, moreover, makes it in general able to repay the application of commercial fertilizer better than any other grain, even where its response in terms of quantity is less. Commercial fertilizer, furthermore, is very important for intensive agriculture in general, and this in turn favors wheat in competition with other grains.

Modern intensive agriculture would also be impossible without modern machinery. Beets, for example, which are very important in strengthening the competitive power of wheat, require plowing both thorough and deep. Thus modern farm machinery materially strengthened the competitive power of wheat in moister regions by facilitating intensive agriculture. And extension of crop production into the steppes of North and South America and Australia, used mainly for the production of wheat, would have been practically impossible without improved machinery.

Every kind of grain owes surprising progress to seed breeding. But wheat is probably the grain which gained most from this. Outstanding developments in wheat selection can be recorded both for moister and for drier regions. The English Squarehead and similar Swedish varieties, in spite of their poor quality, have been significant in the moister regions, while Marquis and Federation have been even more important in the drier regions.*

* Marquis, introduced shortly before the World War and already partly replaced by even earlier or otherwise better varieties (Garnet, Thatcher), greatly extended the Cana-

Rye probably lost most from the strengthening of the competition of wheat. Manure on the whole means less for rye than for wheat. Little rye is grown where modern harvesting machinery is indispensable. Efficient machinery for working the soil is also less important for rye, since much of it is grown on light soil. The only gains which rye can definitely claim are the development of Petkuser rye (the yield of rye in Germany and some other countries is supposed to have been increased 3 bushels per acre by this variety), and the extension of the arable area, primarily in Germany, but also in Denmark and in some other countries, onto sandy soils almost entirely bare of nutrients. With heavy applications of artificial fertilizer and green and/or stable manure these soils, usable only for rye or rye and potatoes, are made to yield fair crops.

The fate of the most recent developments in agricultural technique, incidentally, has been similar to that of some other modern technical achievements. Many countries make their acquaintance with aviation as a means of destruction rather than of anything else. Motor traction on sod land is being developed in many countries much more for war purposes (tanks) than for agricultural work (tractors). Fertilizer, which could be used for the production of bread for the needy, creates these needy in grain-surplus countries by making other countries independent of cheap foreign food supplies.

The specific gains of malting barley from the development of modern technique are probably primarily in quality. The beer of our forefathers undoubtedly could not have been so good as at present, owing partly to the unavailability of suitable barleys. But quantities are assured as well. Except for such obstacles as the lack of sufficient sunshine in Great

dian wheat belt northward. In Australia, the wheat area could not have reached its present dimensions without Federation, a variety introduced early in the present century and since replaced by better varieties to an extent even more marked than with Marquis in Canada. On the history of wheat breeding in Australia see H. Wenholz, "The Improvement of Australian Wheat: Milestones in Its Progress," *The Journal of the Australian Institute of Agricultural Science*, 1935, I, 57-64, 146-55.

Britain, every country now succeeds in growing all the malting barley it needs. Drainage, lime, and artificial fertilizer have been the principal factors in this development.

Other barley has gained from the extension of crop production into the steppe regions of the world (with the help of modern machinery), and the reduction in the proportion of acid soils in other regions has also helped somewhat. The six-row variety Trebi, which in most parts of this country and Canada substantially outyields all other varieties, seems to be the principal contribution of the plant breeders to the fight of non-malting barley for the land.

Oats, one of the less exacting grains, have lost ground owing to most of the developments of the modern technique. However, since oats are more responsive to fertilizer than rye, enlarged use of fertilizer of every kind has not impaired their competitive power as greatly as that of rye. Oats have also gained some new ground through their ability to fit well in any place in rotation. Moreover, the modern technique greatly expanded the need of agriculture for power. Until recently, this meant almost exclusively horse power, and many farmers do not think of any other grain than oats for horses.

Corn also belongs to the grains which lost in competitive power owing to the development of the modern agricultural technique. In some areas, corn may have profited from the recognition of the advantages of leguminous hay and of using manure. But corn has reaped little advantage from its strong responsiveness to commercial fertilizer, since this is most used in countries where climatic conditions are unfavorable to corn.

Corn (like sorghum) involves the relatively smallest waste of labor if it is produced with no other help to man than a few hand tools. It therefore lost through the development of modern machinery, especially through the development of harvesting machinery. Cutting of small grains moved from the scythe through the sickle and the grain mower to the grain binder, while threshing, starting from the flail, reached the stationary thresher; and eventually this development culmi-

nated in performance of both operations by the combined harvester-thresher. But corn grown for grain until recently had to be harvested by the old-fashioned hand-picking procedure, machinery having facilitated only the ingathering of the stover. Moreover, the recently developed corn-picker seems as yet to be short of that perfection which would ensure it the wide distribution observed with regard to harvesting machinery for small grains. It costs less to combine these than to pick corn by machine.⁷ Finally, harvesting ear corn by hand involves incomparably less labor than harvesting (including threshing) small grains by hand. Hence no development in machinery for harvesting ear corn can restore the competitive strength that this grain possessed before the introduction of harvesting machinery for small grains.

The regions with a frost-free period too short for growing corn for grain but adapted for growing corn for silage furnish an exception to the above statement. The development of silage technique and of machinery for silaging opened up these regions for corn production on a moderate scale. Silage helped corn also in some other regions, but probably nowhere to an extent which would compensate it for the strengthening of the competitive position of small grains through the development of modern machinery.

In order to produce the highest yields, corn, more than any other grain, needs varieties adapted to local conditions. Breeding has been successfully solving this problem. The slogan of today is hybrid corn, which is supposed to outyield the regular seed-corn by more than 10 per cent.⁸

⁷ For information on the proportions of wheat, oats, and corn acreages harvested with machinery in the United States, see footnote on p. 369.

⁸ Since the seed has to be renewed every year, hybrid corn resembles the mule. The high cost of the seed diminishes the advantage from the higher yield; this is, however, of greater importance only for regions with low yields. See F. D. Richey, *The What and How of Hybrid Corn* (U.S. Dept. Agr. Farmers' Bull. 1744, January 1935). See also A. A. Dowell and O. B. Jesness, "Economic Aspects of Hybrid Corn," *Journal of Farm Economics*, May 1939, XXI, 479-88.

PART III

COST RELATIONSHIPS

CHAPTER XV¹

COST PER ACRE

Ratios between costs of different grains, rather than absolute costs, are relevant for our study. The ratios aimed at are those of costs computed at uniform rates for land, labor, and other "input" factors. Strictly, ratios between such costs can be used for conclusions as to the competitive position of different crops only where crops similar as to the amounts and seasonal distribution of input are grown either in monoculture or in the same places of rotations. For crops divergent in these respects, only qualified conclusions are possible. But small-grain crops are similar as to the amount of input and largely also as to the seasonal distribution of input. Corn is different, especially as to seasonal distribution. Yet some very broad conclusions are possible also from comparisons of costs of producing corn and small grains computed at uniform rates, and only such conclusions are sought.

The manifold complications involved in computations of costs of producing crops at uniform or other rates and in their interpretation, and the disrepute of any cost computations, appeared to necessitate a rather lengthy discussion. This, however, to such an extent falls outside the scope of the present study that it was felt appropriate to give it space only in the Appendix (Note C).

SMALL GRAINS

Since the small grains in a locality are usually grown in a similar manner, the per-acre costs of production of all small grains tend to differ little. Similar per-acre costs are particularly typical for small grains when all are grown either on stubble or on fallow land, in regions practicing extensive methods of production. Many items of cost are the same for

¹ Thanks are due to A. P. Brodell, Associate Agricultural Economist in the Division of Farm Management and Costs, U.S. Bureau of Agricultural Economics, for valuable suggestions on this and the following chapter.

all grains, and the additional cost due to the commonly higher per-acre yields of coarse grains tends to offset the higher cost of seed for wheat. Wheat, it is true, has also sometimes to be charged for the adverse effect it has on the yield of the crop following it in rotation. The substitution of a winter grain for a spring grain, or vice versa, does not necessarily involve a change in the cost per acre, at least if winterkilling is small.

Under intensive agriculture, there is more opportunity to vary the amount of labor and capital used on each of the small grains. Differences in the fertility of the soil in different places of rotations, which necessitate variation in the charges for fertility or modification in the charge for land use, also tend to be larger in intensive than in extensive agriculture. Yet the per-acre costs of different small grains tend to differ only moderately even in intensive agriculture.

Large differences in per-acre costs of production of the small grains are mostly limited to places where one grain is grown on fallow while the other is grown on stubble.² Since fallowing is practiced mainly in regions with extensive methods of crop production, it is in these regions that per-acre costs of small grains tend to be either most similar or most divergent.

So far as differences in per-acre costs of small grains occur, wheat tends to have the highest cost. But exceptions are regularly found in regions of extensive agriculture where grains are grown in monoculture. The saving on the lower cost of seed for coarse grains in such regions tends to be insufficient to offset the larger cost of harvesting them, for coarse grains are seldom grown in monoculture unless they yield much more heavily than wheat. Moreover, since only one crop is grown, no adverse effect on the yield of the succeeding crop can be present.

The per-acre costs of coarse grains may exceed that of wheat also where all grains are grown by very extensive

² Fallow always means summer fallow, while stubble land means land on which a crop was grown the previous year but does not imply that the land was not prepared for this year's crop.

methods on stubble land in rotation, all of them either as spring-sown or fall-sown. The more intensive the methods of crop production, the larger tends to be the margin by which the per-acre cost of wheat grown on stubble land exceeds the costs of other small grains so grown. Where, on soil adapted to wheat, one grain is grown on fallow while others are grown on stubble, wheat usually gets the privileged place (except in the Russian spring-wheat region). In such regions, the difference between the per-acre costs of wheat and coarse grains—in terms of percentages—may far exceed that observed in regions practicing intensive methods.

Barley and oats tend to have the most similar per-acre costs. In regions of extensive agriculture, it is frequently difficult to ascertain which of the two has the higher cost. In regions of intensive agriculture, the per-acre cost of barley is usually the higher, because much barley produced there is malting barley which warrants greater outlay, and because barley is rather particular with regard to the place it occupies in the rotations. Oats, however, are preferably grown in the poorest places in rotations, and receive also less fertilizer upon the correct assumption that they are good users of fertility left over from preceding crops. Under intensive agriculture, in fact, the per-acre cost of malting barley tends to approximate that of wheat, while the per-acre cost of oats is likely to be similar to that of rye.

The relative per-acre cost of rye displays substantial variations. Where the straw is not saved, rye tends to have the lowest per-acre costs of all small grains, unless grown on fallow; for it gets no more treatment than any other coarse grain, and yields less. Where the straw is saved, the per-acre cost of rye may slightly exceed that of oats owing to the higher cost of saving the large quantity of rye straw. But in such regions as central or northern Russia, where rye is widely grown on fallow and commonly receives most of the manure, its per-acre cost greatly exceeds that of oats, which usually follow it in the rotations.

Under extensive methods.—Analysis of the requirements of different grains with regard to soil preparation, the supply of plant food, and the like, show that there are important reasons for not treating all the small grains in exactly the same way. Wheat and barley are more responsive than rye and oats to good preparation of the land and to the amount of plant food in readily accessible form, and the higher prices of wheat make it more able to repay the additional expense. This practice of varying the preparation of the land has recently found support in the attitude of experts toward plowing. It is recognized that plowing every year does more harm than good to many types of soil. Where crops more or less exacting in respect to the tilth of the land are grown in the same rotation, it is natural to plow the land for the more exacting crops and to limit to lighter operations the preparation for the less exacting crops. But under extensive methods of producing small grains, the expense of land preparation is not large even for the grains that are treated more carefully. Hence all the variations in the cost of land preparation cannot give rise to large divergences in the total expense per acre. Moreover, if it is recognized that plowing one year and disking the other is good practice, it may be advisable to distribute the cost of these operations about evenly between the two (or more) crops involved, disregarding as unimportant the fact that land was plowed for one crop but not for the other.³

The cost of harvesting and marketing⁴ obviously rises as yield increases. The cost of marketing rises in proportion to the yield. The same in general is true for hand-binding of sheaves, and for shocking, stacking, and threshing; but where all straw is saved, the yield of grain and straw rather than of grain alone is the factor determining the cost of these operations. Also, it takes somewhat longer to cut a thick crop

³ This is particularly evident when both crops are either exacting (wheat or barley after wheat or corn) or unexacting (oats after rye).

⁴ In costs of production, marketing includes cleaning and mostly also hauling to the station.

than a thin crop with machinery. The character of the straw—weak or strong—also is a factor determining the differences in the cost of harvesting small grains. The difference in the cost of harvesting a large and a small crop is least if the combine is used.

In regions where the straw is not saved, harvesting oats and barley by binders and stationary threshers costs substantially more than the same operations on spring wheat. Hence it might seem that barley and oats gain from the use of combines. This may be true of small acreages of these grains, especially with regard to the direct costs of harvesting. But if account is taken of all accompanying circumstances, oats and barley may be the losers, particularly if large acreages are involved. Oats tend to lodge badly. "In direct combining, oats must be fully ripe before they can be threshed."⁶ Yet oats tend to shatter more or less freely. Hence "The oat plant will not survive delayed harvest [by combine] as well as wheat or some of the other crops."⁶ The conclusion is: "It is . . . inadvisable to attempt to harvest large acreages of oats with combines unless a portion of the field is windrowed."⁷ Barley also is less adapted to combines than wheat. "Ripe barley straw is usually brittle and crinkles down or breaks off readily or the heads break off easily."⁸ Furthermore, some barleys lodge, and those grown in moister climates shatter. The use of the combine puts oats, and sometimes barley, at an additional disadvantage in regions where their straw is saved while the straw of the other grains is not. Farmers here have the alternative of spending additional time on saving the straw of the oats (or barley) crop which has been harvested with the combine, or sticking to the binder for oats (or barley) while harvesting their wheat with the

⁶ W. M. Hurst and W. R. Humphries, *Harvesting with Combines* (U.S. Dept. Agr. Farmers' Bull. 1761, October 1936), p. 21.

⁶ *Ibid.*, p. 21.

⁷ *Ibid.*, p. 21. Windrowing involves two operations instead of one and is materially more expensive than direct combining.

⁸ *Ibid.*, p. 22.

combine.⁹ The cost of harvesting such grain is enlarged in either case.

Thus under extensive methods of producing small grains, we have either about equal costs of land preparation on all grains or somewhat smaller costs for the less exacting grains (oats and rye), and higher costs of harvesting the more heavily yielding oats and barley. If no large difference in the amount of winterkilling is present, the largest single difference in per-acre costs of the small grains may be in the cost of seed, which is highest for wheat. Where the per-acre costs ex-seed of the other grains are higher than those of wheat, the difference in the cost of seed is an offsetting factor; but sometimes it is a cumulating factor increasing the cost differential against wheat.

Such considerations pertain to small grains grown on stubble land. The use of fallow obviously changes the situation greatly. Fallowing involves land rent, taxes, and some other overhead costs for an extra year, and also considerably more work on land preparation. The question as to proper distribution of the extra costs of fallowing is not answered unanimously in cost studies. The cost of fallowing is mostly charged in full to the first crop, while some students charge part of the outlay to the succeeding crop. In any case the first crop should bear the bulk of the cost, especially where accumulation of moisture is the primary purpose of fallowing; and, consequently, the total per-acre cost of producing a grain grown on fallow becomes considerably larger than the total per-acre cost of grain grown on stubble.

Data obtained in surveys conducted by the Canadian Bureau of Statistics in the Prairie Provinces in 1923 and 1924 may be used to illustrate the costs involved in production of small grains by extensive methods, although small changes in the ratios between the costs per acre of different grains may

⁹ The second alternative seems to be the common one in the United States. According to an inquiry of the Department of Agriculture, in most states the proportion of wheat harvested with the combine in 1938 was considerably larger than that of oats, sometimes several times as large. *Crops and Markets*, July 1939, XVI, 142.

have occurred in the past fifteen years. According to the data in Table 14, in Saskatchewan in 1923 the cost per acre

TABLE 14.—ITEMIZED COSTS OF PRODUCING SMALL GRAINS ON REPORTING FARMS, SASKATCHEWAN, 1923*

(Cost in dollars per acre; yield in cents per acre)

Item	After stubble				After fallow*
	Oats	Barley	Rye	Wheat	Wheat
Preparation	2.59	2.51	2.41	2.46	4.15
Seed .....	.96	.96	.87	1.30	1.40
Seeding .....	.60	.60	.58	.59	.59
Cultivation .....	.49	.48	.44	.51	.60
Harvesting	1.66	1.55	1.50	1.60	1.76
Threshing	3.71	2.91	2.38	2.63	3.38
Cleaning, hauling	1.91	1.68	1.30	1.37	1.72
Wear and tear of implements..	.50	.52	.50	.52	.60
Rental value	2.94	2.98	3.02	2.98	3.80
Total costs (dollars)	15.36	14.19	13.00	13.96	18.00
Average yield (cents)	16.24	14.88	10.64	11.25	14.85

* Canada, Dominion Bureau of Statistics, *Cost of Grain Production in Canada, 1923* (partly reprinted from the *Monthly Bulletin of Agricultural Statistics*, June 1924), 1924, p. 9.

The charges for land preparation and harvesting do not disclose a trace of the fact that wheat is the dominant crop while all other grains with only local exceptions are grown in small quantities. The rental value was designedly computed so as to make sure that all grains grown on the same land would be charged equally for land use (see p. 572). The data can therefore be used to show the relative cost of production of grains at uniform rates with possibly an adjustment for their different behavior as a previous crop.

No provision is made in the questionnaire for the cost involved through winterkilling of rye. The same may be true of the data for North Dakota cited later. Since the average winterkilling and the cost per winterkilled acre are small, the omission is unimportant.

* The cost of fallowing including the extra year's rental value should have been charged in full to wheat after fallow, according to the instructions (*ibid.*, p. 2). Yet the average charge for land use on wheat after fallow as computed was only 28 per cent higher than that for land use on wheat after stubble. If the instructions had been followed precisely, and if the land on which wheat after fallow was grown was similar in quality and location to the land under the other crops, the charge for land use on wheat after fallow should have been twice as large as the charge on wheat after stubble. Since the charge for land use on wheat after fallow actually was only 28 per cent higher than on wheat after stubble, it should be inferred that the land on which the fallowed wheat was grown was materially cheaper than the land used for spring wheat grown on stubble land and for all other grains thus grown, and this might have adversely affected the yield of wheat grown on fallow. On the other hand, to charge the whole cost of fallowing, including the additional year's rental value to wheat grown on fallowed land, may somewhat discriminate against the latter since the grain following fallowed wheat also gains from fallowing.

after stubble did not differ much between spring-sown oats, barley, and wheat, and rye (mostly probably winter rye). It is particularly noteworthy that no significant differences can be observed in the cost of preparing the land. In total per-acre costs of grains produced on stubble, oats cost most and rye least, these differences being caused primarily by variations in yields. For undisclosed reasons (perhaps because the charges for threshing were per bushel of different weights), oats were charged even slightly more for threshing than in proportion to their higher yield. If the computation of costs made in 1923 and 1924 had been repeated in recent years, it would probably have been slightly less unfavorable to oats and barley owing to the use of combines on some farms.¹⁰

Table 14 further shows that wheat after fallow in Saskatchewan in 1923 cost 29 per cent more to produce than wheat grown on stubble. This may be an underestimate, as suggested in the footnote to the table. An up-to-date computation, on the other hand, might favor fallowed wheat, since the small grains are now partly harvested by combine and the additional cost of combining a large crop is slight.

An adjustment of the officially computed costs, for the adverse effect of wheat on the yield of the succeeding crop, may perhaps be necessary. But this effect cannot be large under Canadian conditions, and, where the land is fallowed, the charge may be needed only against wheat grown on fallow, in favor of all grains grown on stubble, wheat included; for the typical crop sequence in western Canada is fallow-wheat-small grain, with wheat frequently also the second crop after fallow.

Except for the possible need of the above adjustment the officially computed costs can reasonably be accepted as costs at uniform rates. Such costs correctly represent the factual situation, and may therefore be considered actual costs where the competition is for the same places in rotations. But the factual situation in the Prairie Provinces is such that coarse

¹⁰ Most farms in Saskatchewan have only small acreages in these grains, in which case barley and oats may be expected to profit from the use of the combine slightly more than wheat.

grains struggle for the position of subsidiary or secondary crops against wheat as the sole crop. Under these conditions certain costs must be charged to coarse grains at lower rates.

A careful study of the costs per acre on reporting farms in 1923 and 1924 reveals no material evidence of an effect of the widely diverging proportions of acreages in different grains on the per-acre costs of wheat grown on stubble (mostly wheat stubble), as compared with the costs of the other small grains which also are grown primarily on wheat stubble. One of the reasons may be found in the method used in computing the costs. But the difference in the rates applicable to the principal and the subsidiary grains seems actually to be small in the specific conditions of western Canada. All spring grains are planted almost simultaneously, while the preparation for winter rye occurs before harvest of spring grains is finished. Oats and spring rye are ready for harvest at about the same time as spring wheat; only fall rye and barley are ripe a little earlier. A somewhat fuller utilization of the factors of production by devoting a portion of the acreage to coarse grains should undoubtedly be possible, however; and it may therefore be accepted that small acreages of coarse grains can be produced relatively more cheaply than is indicated by the official calculations for 1923 and 1924, even without adjustment for the adverse effect of wheat on the yields of crops following it in rotation.

The United States Bureau of Agricultural Economics does not compute costs of production of barley and rye. Hence its data permit only comparisons between the costs of producing wheat and oats among the small grains. The data for North Dakota are perhaps the least risky to use for such a comparison in the hard-spring-wheat region.¹¹ The Bureau does not distinguish costs on stubble land from those on fallow, as was done by the Dominion Bureau of Statistics. Some wheat, however, was undoubtedly grown on fallow in the years to

¹¹ Data averaged for the period 1922-31 are used throughout this study for computations on cost of production made by the Bureau (except in Table 22), because the methods used by the Bureau were changed in 1932.

which the data in Table 15 pertain.¹² In order to make the per-acre cost of wheat comparable to the per-acre cost of oats, as well as to bring North Dakota data to the same basis on which the Canadian data are computed, an adjustment of the North Dakota data for wheat grown on fallow becomes necessary.¹³

Even if the officially computed per-acre cost of producing wheat in North Dakota be reduced by 2-3 per cent in order to bring it down to the per-acre cost on stubble land, it remains somewhat higher than the cost of oats. In Saskatchewan, however, the computations showed the per-acre cost of oats to have been the higher by 6 per cent on the average of 1923 and 1924 (Table 24, p. 394). This difference is to some extent due to the fact that the yield of oats exceeded that of stubble wheat by 45 per cent on the reporting farms of Saskatchewan, but by only about 15 per cent on the reporting farms of North Dakota. A further minor factor is that the difference in price between wheat and oats is slightly larger in North Dakota. (The larger the price difference between the two grains, the larger is the difference in the cost of seed.) Since the data for North Dakota are the more recent, the introduction of combines may have favored oats there, while in Saskatchewan the cost surveys positively antedate combines.

¹² The survey of cost of wheat production conducted by the U.S. Tariff Commission in 1923-24 (*Wheat and Wheat Products*, Washington, D.C., 1924, p. 52) showed some outlay for fallowing in ten of the eleven districts investigated in North Dakota, and gave the average outlay for all districts as 27 cents per acre. M. K. Bennett ("Average Pre-War and Post-War Farm Costs of Wheat Production in the North American Spring-Wheat Belt," *Wheat Studies*, May 1925, I, 180-81) assumed that 6 per cent of the wheat was grown on fallow in North Dakota on the average in 1921-24. See also R. E. Willard and others, *Cost of Production and Farm Organization* (North Dakota Agr. Exp. Sta. Bull. 165, December 1922).

The practice of fallowing has since expanded appreciably. The Agricultural Conservation Office estimated that 1.3 and 2.1 million acres were summer-fallowed in North Dakota in 1935 and 1937, according to information from J. T. E. Dinwoodie, state executive officer. This would be equivalent to approximately 15 and 20 per cent of the total wheat acreage in the two years.

¹³ The propriety of a reduction of the official per-acre cost of wheat in North Dakota, to allow for wheat grown on fallow, is indicated by the results of the official computations themselves. According to them, the average charge for land use was higher on wheat than on oats by 11 per cent, although relatively more oats are grown in the eastern part of the state than in the western and relatively more wheat in the western part, while land is more expensive in the east than in the west.

As was accepted for the Saskatchewan costs, they do not reflect the fact that coarse grains, except locally, are grown only

TABLE 15.—AVERAGE COSTS OF PRODUCING WHEAT, OATS, AND CORN ON REPORTING FARMS IN NORTH DAKOTA AND KANSAS, 1922-31*

(Cost in dollars; yield in cents per acre)

Item	North Dakota			Kansas		
	Wheat	Oats	Corn	Wheat	Oats	Corn
	PER ACRE					
Gross cost	13.70	12.82	14.96	15.60	14.93	13.97
By-product credit (for straw) ..	.22	.49	1.98	.29	.65	.66
Net cost	13.48	12.33	12.98	15.31	14.28	13.31
Land rent	2.65	2.38	2.17	4.20	4.12	4.18
Gross cost, excluding land rent	11.05	10.44	12.79	11.40	10.81	9.79
Yield on reporting farms.....	7.4	8.5	12.2	9.1	9.3	13.3
Yield, state average ^a	6.7	7.3	10.9	8.0	7.5	10.1
	NET COST PER CENTAL					
Including land rent.....	1.88	1.53	1.13	1.73	1.56	1.07
Excluding land rent.....	1.50	1.25	.93	1.21	1.13	.73

* Data kindly supplied by the Bureau of Agricultural Economics, U.S. Department of Agriculture.

The data are not of uniform value for purposes of comparison. Like the data for the Prairie Provinces in Tables 14, 23, and 24, North Dakota data can probably be used to show the relative costs of production at uniform rates, but more corrections may be needed. Cost data for wheat in North Dakota are likely to include some wheat grown on fallow. Data for wheat in Kansas before 1931 hardly included a sufficient charge for losses incurred through winterkilling. Some correspondents of the Bureau might have taken proper account of the expense involved in such losses under some item in the questionnaire, but many might not have done so. Only since 1931 is "a charge for expenses incurred on acreage abandoned and not harvested . . ." explicitly mentioned in the questionnaire as one of the components of the item "miscellaneous costs." The uneven geographical distribution of the oats acreage over the state of Kansas may impair comparability.

Production of corn is concentrated in eastern Kansas and even more so in southeastern North Dakota. The official data on the cost of corn production probably pertain primarily to these sections, and could be considered comparable with costs for wheat and oats only on the assumption that the costs of production of wheat and oats in the corn-producing sections of the states are similar to the average costs in the states as a whole. This assumption may not involve a large error with regard to cost per cental, but it is undoubtedly wrong for cost per acre. The cost of corn, both per acre and per cental, was slightly inflated because the whole cost of manure was probably charged to the crop to which it was applied (see p. 566); in North Dakota corn favorably affects the yields of small grains which follow it in rotation and deserves some compensation for this service. The same is true of Kansas, except when the crop grown after corn is winter wheat.

^a Average of 1911-32 for Kansas.

in small quantities. We are reluctant to make such a supposition with reference to the North Dakota data; but if for that reason the cost of oats as officially computed was lowered relative to that of wheat, the reduction was only small. Although there remains some residual difference between the Canadian and North Dakota data after allowance for differences in yields and prices (we must leave this difference unexplained), the data of both regions or, let us say, of both sources, can be considered as in reasonable agreement.

Except for the possibility that the per-acre cost of oats was somewhat lowered relative to that of wheat by the fact that oats are a minor crop in North Dakota, we are inclined to accept the ratio between the corrected official costs of wheat and oats as ratios between costs computed at uniform rates.

Other things equal, one expects a slightly higher per-acre cost of barley than of oats in North Dakota because the cost of land preparation should be at least as large for barley as for oats, while the harvesting and marketing of the higher-yielding barley costs somewhat more. Yet computations of the North Dakota Agricultural Experiment Station gave a slightly lower per-acre cost of barley in 1921-23 (\$12.66 as against \$12.96) in spite of an insignificantly higher yield of barley.¹⁴ The difference obviously lies within the probable error of the data. A charge in favor of barley for being a better preceding crop than oats (see p. 321) would bring the per-acre cost of barley below the cost of oats anyway.

Rye production in North Dakota—or at least part of it—may constitute an exception to the rule that per-acre costs of small grains grown on stubble land by extensive methods tend to differ little. The computations of the North Dakota Agricultural Experiment Station showed for the period 1921-25 an outlay per acre of rye of only \$9.22 as against \$12.83 spent on wheat.¹⁵ If the data were representative, rye in North Dakota was widely sown without any land preparation

¹⁴ R. E. Willard, *Cost of Producing Crops in North Dakota* (North Dakota Agr. Exp. Sta. Bull. 199, July 1926), p. 15.

¹⁵ *Ibid.*, pp. 14-15.

whatever; for although some rye must have been grown on fallow (probably on poor land unsuitable for wheat), only 88 cents' worth of labor and 90 cents' worth of horse power were spent on all operations per acre of rye on the average in 1922-25.¹⁶ Modest as rye is in its requirements as to soil preparation, it would not grow on unprepared land unless another crop had been grown on the land in the preceding year. Thus rye, even if drilled in directly in stubble land, should have been rightfully charged something for preparation of the land. But even if such adjustment were made of the per-acre cost as computed by the Experiment Station, the per-acre cost of rye would remain substantially less than that of any other small grain. The per-acre cost of rye as computed by the station can obviously be valid only for a crop grown in small quantities. It would not lose this character if the proposed adjustment were made.

Much wheat and barley are grown in California in monoculture, in alternation with fallow every second year. Thus there are no effects of one crop on the succeeding one to be considered, and uniform rates for use of labor and capital are properly applied to both grains without limitations. Another peculiarity is that in the Pacific states grain is handled in sacks. Although lighter and cheaper sacks are used for barley, sacks cost more for barley than for wheat, not only per acre but even per cental of grain. Combining barley, which usually is rather badly lodged, also costs more in California even per cental of grain; the *per-acre* cost of combining barley may be higher than that of wheat by 50 per cent or more. Still, the total per-acre cost of barley is estimated to be only about 5 per cent higher than that of wheat.¹⁷

The officially computed per-acre costs of oats and wheat in Kansas given in Table 15 are exactly the same except for the additional cost of wheat seed. As the figures stand, the per-acre cost of wheat exceeds that of oats by 5.5 per cent. This percentage would be in the neighborhood of 10 if losses

¹⁶ *Ibid.*, p. 19.

¹⁷ Personal information from Professor R. L. Adams, University of California.

from winterkilling of wheat were fully considered. The cost ratios thus computed may be regarded as representing approximately ratios between costs at uniform rates.¹⁸

The situation with regard to per-acre cost of production of small grains by extensive methods is more or less similar everywhere. It is pertinent to mention that in the third broad investigation of the cost of producing principal grains in Russia (1916)¹⁹ it seemed appropriate to compute the cost up to and inclusive of seeding for all winter grains together and for all spring grains together, distinguishing the individual grains only in the computations of the cost of harvesting and marketing. This procedure could be used only because the very extensive methods of producing rye, which seem to have been in wide use in North Dakota at the time Willard made his study, were in vogue in Russia only in a very limited area, and even there only part of the rye was grown in this way.

In the Corn Belt.—The gross cost per acre of oats in 1922–31 averaged less than that of wheat by only 10.7 and 15.7 per cent in Iowa and Illinois, respectively, according to official computations given in Table 16. It may be accepted that the data pertain specifically to spring oats and winter wheat, since hardly any winter oats and very little spring wheat are grown there.

A general statement that an acre of wheat in the Corn Belt costs so much more than an acre of oats is rather meaningless. The ratio depends on the places the grains occupy in the rotations. At least three situations have to be distinguished: (1) winter wheat and oats compete for the place in rotations after corn; (2) winter wheat is grown after oats which follow corn (because the growing season is too short for growing winter wheat directly after corn), with the alternative of hay

¹⁸ No definite check is possible, but the data do not impress one as if materially lower rates for use of factors of production were charged on oats, the minor crop, than on wheat, the dominant crop. The data are also insufficient to justify a charge on wheat for its possible adverse effect on the yield of oats following it.

¹⁹ Russia, Ministry of Agriculture, *Cost of Producing Principal Grains in 1916* [translated title] (Petrograd, 1916). The first two similar investigations covered the years 1888 and 1913. The most recent study of this subject is the *Cost of Producing Crops* [translated title] (Moscow, 1929), which deals with costs in 1925.

after winter wheat as the fourth crop; and (3) oats and winter wheat are grown in rotations not including corn. The analysis will be limited to Case 1 because Case 2 involves too much arbitrariness while Case 3 has no practical significance.

The ratios between the per-acre costs of producing winter wheat and oats as officially computed for Iowa and Illinois may be approximately valid for these grains as being grown after corn in the south of the Corn Belt—for example, in southern Illinois, where the growing of winter wheat after corn meets with no great difficulties. The true ratios, how-

TABLE 16.—AVERAGE COSTS OF PRODUCING CORN, WHEAT, AND OATS ON REPORTING FARMS IN IOWA AND ILLINOIS, 1922-31*

(Cost in dollars; yield in cents per acre)

Item	Iowa			Illinois		
	Corn	Oats	Wheat	Corn	Oats	Wheat
	PER ACRE					
Gross cost	25.14	19.10	21.40	21.49	16.60	19.69
Credit for straw.....	.89	1.28	1.03	.87	1.24	.91
Net cost	24.25	17.82	20.37	20.62	15.36	18.78
Land rent	8.69	7.94	8.10	6.65	6.39	6.30
Gross cost, excluding land rent	16.45	11.16	13.30	14.84	10.21	13.39
Yield on reporting farms.....	24.5	13.2	12.7	22.1	11.7	11.3
Yield, state average: 1922-31...	21.3	11.5	11.6	19.7	10.4	10.4
1927-36...	19.5	9.9	10.7	18.0	9.3	10.1
	NET COST PER CENTAL					
Including land rent.....	1.00	1.34	1.62	.95	1.31	1.70
Excluding land rent.....	.64	.75	.98	.64	.78	1.13

* Data kindly supplied by the Bureau of Agricultural Economics, U.S. Department of Agriculture.

The cost of manure was probably charged to the crop to which it was applied (see p. 566). This cost (excluding the cost of applying the manure) amounted in Iowa in 1923 to \$2.16, \$0.42, and \$0.61 per acre of corn, oats, and wheat, respectively (see Table 22, p. 379). If the cost of manure (excluding the cost of applying it) were distributed according to the use each crop makes of it, oats should have been charged at least 60 cents per acre more than it actually was, and wheat too would have to be charged more. As to the insufficient consideration of winterkilling in the cost of winter wheat, see footnote to Table 15 (p. 355), but the amounts involved are much less than in Kansas. Other necessary adjustments are discussed in the text.

ever, are likely to be slightly less favorable for wheat than the officially computed ones. The charge on oats for manure would have to be somewhat increased;²⁰ but wheat ought properly to be charged for the loss from winterkilling (see footnote to Table 15), and the yield of corn after oats may be slightly larger than after winter wheat.²¹

As we move north, the difficulty of following corn with winter wheat becomes stronger, and wheat has to bear—in comparisons of costs of growing winter wheat and oats—the additional cost arising from the necessity of removing the corn crop from the field immediately after it ripens instead of leaving it for the cheaper hand-picking from standing stalk, and/or the loss from growing an earlier but less productive variety of corn. Since winterkilling also becomes heavier northward, the ratio between the per-acre costs of winter wheat and oats grown after corn somewhere in central Illinois must be substantially less favorable to wheat than is shown by the official data. In the eastern part of the Corn Belt, where the whole corn crop is removed from the field anyway, the additional cost for prompt removal is less than in the corresponding portions of the western part of the Corn Belt. The ratio between the per-acre costs of winter wheat and oats therefore becomes more favorable for wheat from west to east.

Provided the land is adapted to barley, this grain can be grown in the Corn Belt in the same places in rotations as oats. The gross cost per acre of barley grown after corn in the Corn Belt is probably slightly higher than that of oats, for barley needs the more thorough preparation.²² In *net* per-acre costs

²⁰ Oats were not charged for the residual effect of the manure applied to corn that usually precedes oats in the rotations in the corn states (in 1923, for example, oats were charged less than half as much for manure as was wheat).

²¹ Where hay is included in the rotations, winter wheat grown in place of oats may affect adversely the yields of all crops grown in the rotation.

²² According to J. A. Hopkins, Jr., *The Crop System in Iowa County* (Iowa Agr. Exp. Sta. Bull. 261, June 1929), pp. 297, 300, the gross cost exclusive of land rent in Iowa County, Iowa, in 1925-27 was \$11.37 per acre of barley and \$10.81 per acre of oats. But in Walworth County, Wis., which may not be quite typical of the Corn Belt, the average cost of an acre of barley in 1922-24 was computed at slightly less than that of oats (\$22.08 as against \$22.38). P. E. McNall and L. S. Ellis, *Farm Costs and Practices in the Production of Walworth County Crops and Livestock* (Wisconsin Agr. Exp. Sta. Research Bull. 83, April 1928), pp. 27, 36.

the difference is further enlarged owing to the higher value of the oat straw. But the difference is small, even in net costs.

Under intensive methods.—It is much easier to vary the expenses per acre of the different small grains under conditions of intensive agriculture, where much more labor and power is used on the preparation of the land and on care of the growing plants than in regions of extensive agriculture, and where immense amounts of manure and/or fertilizer are applied. Yet the extent of variation in the per-acre costs of small grains is rather limited even under conditions of intensive agriculture, unless the charge for land use is substantially varied for different grains.

Nearly a fourth of the per-acre cost of oats in eastern Canada is made up of the cost of manure, according to the Hopkins study.²³ Thus the methods of growing crops are intensive. Yet the investigators did not think it worth while to deal individually with each small grain, and the following statement appeared: "As the cost of producing barley and wheat is practically identical with the cost of producing oats, detailed information regarding this cost may be obtained by referring to the statement on the oat crop."²⁴ A detailed analysis in our opinion would probably have shown some divergences worth knowing, especially if the roles of each crop as a previous crop had been taken into account; yet the omission of a separate analysis for each small grain would hardly have occurred unless the per-acre costs were really very similar.

In the state of New York the per-acre cost of producing wheat on accounting farms exceeds those of oats and barley by only slightly over 10 per cent, according to the Cornell Agricultural Experiment Station. In 1914-31 the costs averaged \$39.40 for wheat, \$34.60 for oats, and \$34.90 for barley.²⁵ The rotations followed in such a large state vary, and it seems impossible to ascertain if adjustments in the

²³ E. S. Hopkins and others, *Cost of Producing Farm Crops in Eastern Canada* (Canada Dept. Agr. Bull. 115, New Series, June 1929). ²⁴ *Ibid.*, p. 15.

²⁵ J. F. Harriott and L. M. Vaughan, *Cost Accounts on New York Farms* (Cornell Agr. Exp. Sta. Bull. 554, April 1933). The cost of manure was distributed, perhaps too cautiously, by charging 40 per cent of it to the first crop, 30 per cent to the second, 20 per cent to the third, and 10 per cent to the fourth.

costs as computed are needed to make them comparable. Oats, for example, might have been grown in worse places in the rotations than wheat and barley.

The situation in regions of western Europe practicing intensive methods is illustrated by data from two studies by Peters.²⁶ He was in charge of the accounting department of the Deutsche Landwirtschafts-Gesellschaft, where accounts are kept for a large number of farms throughout Germany, mostly big estates. Peters' computations were made for the purpose of showing the great losses incurred by German grain producers in postwar years (how many other computations were and are made for similar purposes!), and should therefore be viewed with reserve so far as their absolute level is concerned. But the data were based on accounts of the same farms over a rather long period, and there was no reason to accord preferential treatment to a particular kind of grain. The second of Peters' studies contained data on the cost of producing winter wheat, winter rye, and spring barley per quintal (the cost of winter wheat is given also per hectare), and the average yields, on 80 estates in central Germany (Table 17). The earlier study was less comprehensive as to number of estates,²⁷ but covered more grains and presented detailed information on the composition of costs.

From Peters' earlier study, it is clear that winter rye received much less manure than winter wheat,²⁸ and somewhat less commercial fertilizer. Also fewer operations were involved; but the moderate saving of labor on rye thus attained was offset—in part or even fully—by the additional work of handling the larger amount of rye straw. Since the charge for land use was the same for both grains, all of the lower charges on rye than on wheat, including saving on the cost of

²⁶ A. Peters, "Erzeugungskosten der wichtigsten Fruchtarten vor und nach dem Kriege," *Mitteilungen der Deutschen Landwirtschafts-Gesellschaft*, 1929, XLIV, 224; and "Produktionskosten in der Landwirtschaft," *ibid.*, 1930, XLV, 482-85, 508-11.

²⁷ It included 19 estates in Anhalt and 8 in Mecklenburg.

²⁸ Directly and by way of residual effect. Manure was charged at the rate of 50 per cent to the first crop, 30 per cent to the second, and 20 per cent to the third.

TABLE 17.—AVERAGE COSTS OF PRODUCING WINTER WHEAT, WINTER RYE, AND SPRING BARLEY IN GERMANY*

Period	Cost per hectare (marks)			Yield per hectare (quintals)			Cost per quintal (marks)		
	Winter wheat	Winter rye	Spring barley	Winter wheat	Winter rye	Spring barley	Winter wheat	Winter rye	Spring barley
WEST ANHALT (48 ESTATES)									
1910-14..	484	...	...	29.9	23.8	28.2	16.7	17.1	16.5
1924-27..	612	...	...	27.2	24.0	26.2	25.2	26.4	24.1
1927-28..	681	...	...	26.3	25.1	27.2	27.7	26.6	25.8
1928-29..	669	...	...	29.9	25.7	34.8	25.2	27.5	20.5
LEIPZIG-DELITZSCH (21 ESTATES)									
1910-14..	374	...	...	26.6	22.6	23.6	13.8	14.2	16.2
1924-27..	539	...	...	27.2	23.3	22.5	22.4	24.3	28.6
1927-28..	579	...	...	24.5	24.3	21.1	25.8	25.1	30.9
1928-29..	582	...	...	28.8	26.7	27.2	23.0	22.9	23.7
SILESIA (11 ESTATES)									
1910-14..	381	...	...	26.0	21.0	25.5	14.7	15.6	14.0
1924-27..	507	...	...	22.3	19.1	21.2	26.6	28.0	27.4
1927-28..	569	...	...	22.5	19.5	24.2	26.3	27.7	23.9
1928-29..	...	...	...	....	....	....	....	....	....

* A. Peters, "Produktionskosten in der Landwirtschaft," *Mitteilungen der deutschen Landwirtschafts-Gesellschaft*, 1930, XLV, 482-85, 508-11. The costs were computed from accounts of large estates. The cost per hectare pertains to unthreshed grain at the barn. The cost per quintal does not include the cost of hauling to the railway station. Rye has been discriminated against by charging all crops an equal amount for land use.

seed, amounted to only about 15 per cent of the total per-hectare cost in prewar years and about 10 per cent in post-war years.²⁹

Identical charges for land use on winter wheat and winter rye are hardly correct, it is true. Rye undoubtedly is assigned more frequently than wheat to poor places in the rotations. The possibility of using such places for this less exacting grain is one of the principal reasons for growing it on soils adapted to wheat. A less important reason may be that a

²⁹ Differences in the per-hectare costs have to be computed from the cost of producing grain per quintal multiplied by the yields, since Peters provided data on per-hectare cost of winter wheat only.

winter grain is desired in the rotation more often than winter wheat can properly be grown. Also, farms having land of different quality are likely to have used the better land for wheat in preference to rye. A readjustment of the charge for land use would have materially increased the margin between the per-hectare costs of winter wheat and winter rye.

The outlay per hectare of spring barley on the German estates covered by Peters' later study (see Table 17) did not differ substantially from the outlay on winter wheat.³⁰ The condition of the soil was hardly worse when barley was sown on it than when it was occupied by winter wheat; it also is unlikely that poorer soils were used for barley. Hence no adjustments probably need be made in Peters' uniform charge for land use. Since the other costs also were likely to have been charged to all grains at uniform or approximately uniform rates, the ratio between the computed costs of winter wheat and spring barley may be accepted as a ratio between costs at uniform rates.

According to Peters' earlier and less comprehensive study, the costs of production per hectare (in German marks) were as follows:

Grain	Anhalt		Mecklenburg	
	1910-11 to 1913-14	1924-25 to 1926-27	1910-11 to 1913-14	1924-25 to 1926-27
Winter wheat.....	441	562	384	476
Spring wheat.....	413	521	...	...
Winter rye.....	376	513	354	400
Winter barley.....	...	528	...	393
Spring barley.....	406	508	341	421
Oats.....	399	514	330	389

Apparently no difference between grains in per-hectare costs exceeded 20 per cent. This remains approximately true, even if an adjustment is made for the differences in the soils, or the fertility of the soil in the different places in rotations, as used for different grains. The per-hectare cost of

³⁰ See preceding footnote.

producing winter barley as computed was approximately as large as that of winter rye; but a somewhat lower charge for land use on winter rye than on winter barley may have been justified. The cost of oats also probably would need downward adjustment to allow for the less fertile condition of the soil occupied by this grain.

Irrigated land should probably be classed as land to which intensive methods are applied. In so far as the intensity is mainly limited to application of irrigation water, however, there is no reason to expect a material divergence in the per-acre cost of small grains. Matlock and Clark, for example, computed the per-acre cost of wheat in the Salt River Valley, Arizona, in 1930 at \$21.99, and that of barley at \$22.90.³¹

Barley usually needs one less watering than wheat. Since barley is more drought-resistant and cheaper than wheat, it may also be advisable to give it less water in each watering if the cost of irrigation water is approximately proportionate to its amount. This is the case where water is pumped in a primitive way by animal or human power. In British India and some other countries (formerly to a very large extent in Egypt), where this practice of procuring irrigation water is widespread, barley seems commonly to be given considerably less water than wheat. The practice was apparently reflected in the computation of the cost of producing wheat and barley in Bengal, India, by Mukerji,³² who charged wheat for one regular irrigation with 2Rs. 8as. and barley with only 1R. 8as. for "irrigation if necessary."

CORN

Corn is the grain that tends to have the highest per-acre cost of production computed at uniform rates. Not this quantitative difference, however, but qualitative divergences in methods of production make it advisable to discuss the per-

³¹ R. L. Matlock and S. P. Clark, *Production Costs and Returns from Major Salt River Valley Field Crops, 1928-1930* (Arizona Agr. Exp. Sta. Bull. 146, March 1934), p. 49. Barley yielded about 7 per cent more than wheat.

³² N. G. Mukerji, *Handbook of Indian Agriculture* (3d ed., Calcutta, 1915), pp. 189, 191.

acre cost of corn separately from those of small grains; for substantial differences in per-acre costs are observed between small grains also, and the per-acre cost of corn in some regions is less than or equal to the per-acre cost of certain small grains.

Corn is the only row crop among the grains widely grown in the temperate zone.³³ The method of harvesting corn is also different. Owing to these differences as well as those caused by climatic requirements, corn differs from the small grains in the amounts of labor, power, and other capital applied and in the time when they are applied. On the same grounds, corn displays the largest interregional variations in per-acre cost. In some regions an acre of corn involves less cost than an acre of wheat, which usually is the small grain with the highest per-acre cost, or the difference is small if the per-acre cost of corn is higher than that of wheat. In some other regions, however, the per-acre cost of producing corn materially exceeds that of wheat, and not rarely the excess is very large.

One of the important factors bringing about differences between the per-acre costs of corn and small grains is the intensity of the methods employed in growing (as contrasted with harvesting) the crop. The difference in per-acre cost tends to be least where the methods are extensive, and especially where no manure or other fertilizer is used. Under these conditions the difference in methods of growing corn and small grains is merely that corn is cultivated, while usually no work is done on small grains from seedtime to harvest. The cost of cultivating corn may be to a large extent offset by the much smaller cost of seed for corn than for wheat, and the per-acre costs of both grains up to harvest be almost equal.

Manure, however, commonly brings about a divergence. Since corn responds best to manure, all or most of it is applied to corn. Utilization of artificial fertilizer may have the same results except where the price of wheat is much above that

³³ Sorghum and pearl millet are other such grain crops; but pearl millet is not grown in moderate climates and sorghum is not widely grown there except in relatively restricted areas.

of corn. In general, the more intensive the methods of growing the crops, the more the per-acre cost of growing corn tends to exceed those of small grains.

The method of handling the stover in harvesting corn is another factor responsible for the differences in the per-acre cost of corn and small grains. Small grains cannot be harvested without cutting the straw. Corn stalks, however, are cut only when they are saved otherwise than by pasturing. It costs much less to harvest the ears from standing stalk than to harvest the whole plant.³⁴ In spite of the commonly much higher yield of corn grain, harvesting ear-corn by hand with the stover left standing in the field usually costs less per acre than harvesting small grains with binder and thresher. Harvesting both the ear-corn and stover, however, usually costs more than harvesting small grains. This may be illustrated by the following comparisons of costs of harvesting corn and wheat in 1923 in states of which some usually save stover and some do not:³⁵

State	Corn		Wheat	
	Yield per acre (centals)	Cost of harvesting (dollars)	Yield per acre (centals)	Cost of harvesting (dollars)
States saving stover:				
Ohio	27	7.26	13	5.29
Pennsylvania	27	8.27	13	5.84
New York	22	6.51	15	6.21
States not saving stover:				
Iowa	26	3.38	12	4.13
Illinois	23	3.04	13	4.21
Nebraska	20	2.86	8	3.90
Kansas	15	2.15	8	4.17

³⁴ Cutting and removing the corn without husking cost about \$3.00 per acre in Putnam County, Ohio, in 1926-28. J. F. Dowler, *Some Factors Causing Variations in Crop Production Costs in Putnam County* (Ohio Agr. Exp. Sta. Bull. 481, July 1931), p. 18.

³⁵ *Agriculture Yearbook, 1924*, pp. 1134, 1136. An early year was chosen because no combines and a negligible number of mechanical corn pickers were then employed in the states considered, and because the number of reporting farms was much larger in earlier years than recently.

The cost of harvesting wheat in the states not saving the stover was higher than the cost of harvesting corn, though only a small part of wheat straw was saved in Nebraska and Kansas and not all of it was saved in Iowa and Illinois, and though in these states labor employed in the corn harvest undoubtedly was more expensive than that used in the wheat harvest. But the recent developments in harvesting machinery, combines for small grains and mechanical pickers for corn, tend to bring about changes to the disadvantage of corn. There are conditions under which a mechanical picker for corn means a greater cut in per-acre cost than a combine for small grains (heavy yield of corn and high wage rates for labor used in the corn harvest; straw but not stover saved). But a greater saving on the cost of harvesting small grains seems to be more frequent. Where neither straw nor stover is saved, the cost of combining small grains tends to be a cheaper operation than that of picking corn by machine, whereas the reverse obtains under practices now prevailing.

Where corn is grown intensively, the stover usually is saved by cutting, but it is usually not saved in regions of extensive agriculture. Since intensive methods of crop production tend to enlarge the cost of growing corn more than those of small grains in any case, both effects become cumulative. This is another reason why per-acre costs of corn tend to show larger interregional dispersion than do similar costs of small grains. Where cultural practices are very extensive and the stover is not saved, the per-acre cost of producing corn tends to be lower than that of wheat or at least not materially higher. Such is the situation, for example, in the southwestern portion of the Corn Belt and in some Argentine regions. On the other hand, in regions where all grains are grown under intensive methods, and the stover is saved, the per-acre cost of corn tends greatly to exceed that of wheat. In New York state, for example, an acre of corn may cost about 40 per cent more than an acre of wheat.

There are, it is true, important exceptions to the rule that

stover is saved where intensive methods of corn production prevail. Where corn is at its best, so much is grown that the stover has little value, and it may be left uncut even though production is moderately intensive. The heart of the Corn Belt produces corn by such methods, yet the stover is not cut. In the Danubian countries, on the other hand, where methods of production are in part less intensive than in the Corn Belt, stover is probably never left in the field.

Further variations in the relation between the per-acre costs of corn and small grains are brought about by the fact that corn needs more labor and less machinery than small grains. While corn is always cultivated, work on small grains between seeding and harvesting is usually done only in regions of the most intensive agriculture. More manure, which is commonly applied to corn, likewise means more labor. Small grains are much more widely harvested by machinery than is true of corn. In the United States harvesting small grains by hand has long since practically disappeared, while hand picking of corn ears is still the standard practice.²⁸ Where the corn ears are picked by hand and the stover is saved, more labor is used in harvesting an acre of corn than one of small grains harvested and threshed by machines. All operations considered, an acre of corn usually needs more labor, and also such type of power as is supplied by horses, but requires the smallest outlay for machinery. Hence the level of wages and the prices of machinery are important in the competition of corn with small grains. Cheap power for field work and cheap labor tend to alter the ratio of per-acre costs in favor of corn, while low prices of machinery and low interest rates favor small grains. In this, corn has a certain advantage over small grains in Argentina, in the Danubian countries, and especially in the Union of South Africa, as compared with the situation in the United States.

²⁸ According to an inquiry of the Department of Agriculture, only 4 per cent of wheat acreage and 7 per cent of oats acreage were harvested in 1938 by methods other than combining or binding, i.e., by methods which may include hand harvesting. But only 13 per cent of the corn acreage harvested for grain was harvested with mechanical corn pickers. *Crops and Markets*, July 1939, XVI, 142.

The cost of harvesting by hand is approximately proportionate to the *crop*, while the cost of harvesting by machinery depends largely on the *area* harvested. Since corn is to a lesser extent harvested by machinery, the difference between the yields of corn and small grains affects the difference in their per-acre costs more than the difference between the per-acre costs of small grains is affected by the difference in their yields. Such an effect is noticeable, for example, in the comparison of per-acre costs in the southwest of the Corn Belt with those in Argentina.

Finally let us mention two factors of a more general character affecting costs of producing corn and small grains. Since the peaks of power and labor requirements of corn occur at times different from corresponding peaks in the production of small grains, a crop combination of two small grains, especially if both are either fall-sown or spring-sown, seldom permits as efficient utilization of all the means of production as does the combination of corn—small grain. In computations of actual costs, therefore, the differences in the rates chargeable to principal and subsidiary crops are much greater in rotations consisting of corn and small grains. Some corn can in fact be produced on many farms growing small grains with no extra labor and power than those needed in production of small grains, and vice versa. The more economical use of labor and capital, coupled with the favorable effect of corn on the yield of small grains following it in rotation and, in regions well supplied with moisture, with the favorable effect of rotations on the yield of corn, bring it about that corn penetrates deeply into regions with weather conditions rather unfavorable for it and that, on the other hand, much small grain is grown in regions climatically very favorable for corn.

In discussing the ratios between the costs of producing winter wheat and spring grains, we favored charging winter wheat for the additional costs involved where a spring grain is replaced by winter wheat in the combination corn—small grain. If, in the combination winter wheat—another grain, corn can-

not be grown after winter wheat or involves some losses or extra costs which are not encountered if a spring-sown small grain is placed after winter wheat, the loss or costs involved have to be charged to corn in comparisons between the costs of producing corn and spring-sown small grains.³⁷

Under extensive methods.—Tables 18 and 19 below present a typical situation in a region where the climate necessitates very extensive methods of corn production. Only 7.34 man hours and about 26 horse hours (including tractor work converted to horse hours) per acre of corn prior to harvest in 1935 were used in Douglas County, Nebraska (Table 18); the other three counties covered in Table 19 each used even smaller amounts of labor and power.³⁸ In harvesting 27 bushels of corn per acre, the reporting farmers of Douglas County used only 3.59 hours of man labor on the average in 1935, although mechanical pickers evidently were not in operation.³⁹ No manure was used.

In every county (Table 19) the per-acre cost of producing winter wheat (without the charge for land use) was higher than that of corn. Almost no wheat was combined, it is true. Combining all the wheat might have brought the per-acre cost of winter wheat below the level of the per-acre cost of corn, at least at more normal wages than the average wages charged in the computations.⁴⁰

It was accepted (p. 567) that corn can properly claim a remuneration for its beneficial effect on the yield of the crop following it in rotation. But this effect may be absent if winter wheat is the succeeding crop and the time available for land preparation is insufficient; under these circumstances,

³⁷ These charges are equivalent to charging corn more for land use than spring-sown small grains, as suggested on p. 568.

³⁸ Only 4.61, 5.20, and 3.71 man hours were used on the average on corn up to husking in Cass, Saunders, and Fillmore counties, respectively.

³⁹ At the rates of labor and power that prevailed in Nebraska in 1935 (see asterisk footnote to Table 18) and the yields obtained there, harvesting with mechanical pickers might have been more expensive than hand picking.

⁴⁰ Most of the years for which the costs were computed were depression years with very low wages in that region.

COMPETITION AMONG GRAINS

TABLE 18.—PHYSICAL REQUIREMENTS AND COSTS OF PRODUCTION PER ACRE OF CORN AND WHEAT TO THE TENANT ON REPORTING FARMS IN DOUGLAS COUNTY, NEBRASKA, 1935*

Item	Corn	Wheat
Labor and power (<i>hours</i>)		
To harvest:		
Man	7.34	6.14
Horse	18.37	7.13
Tractor	1.03	1.39
Harvest:		
Man	3.59	6.32
Horse	7.18	7.82
Tractor .....	.....	0.66
Cost per acre (<i>dollars</i>)		
Man labor	2.94	1.23 ^a
Power	3.07	1.70 ^a
Equipment	1.17	0.47 ^a
Seed	0.20	1.16 ^a
Total cost up to harvest .....	.....	4.56 ^a
Harvesting and threshing cost .....	.....	4.27
Total cost per acre harvested	7.38	9.03
Acres harvested	74.4	23.6
Yield per acre (<i>centals</i>)	15.4	10.1
Tenant's yield	8.9	6.1
Tenant's cost per cental (<i>dollars</i>)	0.82	1.50

* Data from A. G. George, *Corn Production Costs, Nebraska, 1935* (Nebraska Agr. College Extension Circ. 840, January 1936), and A. G. George, *Winter Wheat Production Costs, Nebraska, 1935* (Nebraska Agr. College Extension Circ. 839, December 1935).

The following rates were used:

Unpaid and regular hired help....	20 cents per hour
Day labor	Wages actually paid
Board for day labor.....	75 cents per day
Horse power	9 cents per hour
Tractor power 2-plow	65 cents per hour
Tractor power 3-plow	100 cents per hour
Tractor power 4-plow	110 cents per hour
Combining	150 cents per acre

Since the computation covers only the tenant's expenses and his share of the crop, a charge for land use was not included. The cost of corn production was favored by the low wage rate, while the practical absence of winterkilling in the year specified favored the cost of wheat.

^a "Cost up to harvest," based on acres seeded (24.6); with 23.6 acres harvested, the cost per acre to harvest was \$4.76, if based on harvested acreage.

yields of winter wheat may even be impaired. Preparing a good seedbed for winter wheat after corn has been husked

TABLE 19.—COSTS OF PRODUCING CORN AND WHEAT TO THE CROP-SHARE TENANT IN SPECIFIED COUNTIES OF EASTERN NEBRASKA, AVERAGES OF THE YEARS 1927-33 AND 1935*

County	No. of records, 1935		Cost per acre		Cost per cental	
	Corn	Wheat	Corn	Wheat	Corn	Wheat
Cass	9	5	\$ 8.15	\$ 9.29	\$.70	\$1.17
Douglas	31	8	10.07	10.29	.89	1.32
Saunders	19	28	8.27	9.41	.80	1.17
Fillmore	18	30	7.10	7.92	.93	1.23
Unweighted average...	..	..	8.40	9.23	.83	1.22

* Sources as for Table 18. The cost does not include a charge for the use of land. The cost per cental was obtained by dividing the tenant's expenses by the tenant's share of the crop.

from standing stalk is difficult even in Kansas. Thus the experiment station at Manhattan has found it necessary to change the sequence corn, corn, wheat to the sequence corn, wheat, wheat in the 16-year experimental rotation. Throckmorton and Duley⁴¹ comment: "During the early years of this . . . [experiment] the wheat was somewhat at a disadvantage because it was always seeded after corn."⁴² Little winter wheat, in fact, is grown after corn in Kansas (see p. 255). So far as wheat does follow corn, the rotation—both in Kansas and Nebraska—is frequently changed from corn, winter wheat to rotations of the type corn, corn, winter wheat, winter wheat. Under these conditions, no charge in favor of corn preceding winter wheat in the rotation is appropriate.

The costs of producing corn and winter wheat as computed for some Nebraska counties by the College of Agriculture do not include a charge for land use. Provided equal charges rather than the shares actually received by the landowners

⁴¹ R. I. Throckmorton and F. L. Duley, *Twenty Years of Soil Fertility Investigations* (Kansas Agr. Exp. Sta. Tech. Bull. 40, October 1935), p. 17.

⁴² The unfavorable effect of hasty preparation of corn land for winter wheat is of course not limited to regions employing extensive methods of crop production. On investigated farms in Medina County, Ohio, winter wheat on disked corn land yielded 13.0 bushels, while it yielded 18.0 on plowed out land (averages for 1921-24). F. L. Morison, *Variations in Crop Production Costs in Medina County, Ohio* (Ohio Agr. Exp. Sta. Bull. 453, June 1930), p. 29.

are added to them, the costs are costs at approximately uniform rates.

The per-acre costs of production in the whole state of Nebraska, as computed by the Bureau of Agricultural Economics for the average of 1922-31, were also slightly less for corn than for wheat (the gross cost was \$16.24 for corn and \$16.98 for wheat), even though relatively more corn is grown in the eastern part of the state where per-acre costs of production of all grains should be higher than in the west. The situation in Kansas (Table 15, p. 355) is similar.⁴³

Only about twenty-five years ago, the average per-acre cost of corn in Argentina was supposed to be lower than that of wheat. Both crops were produced under very extensive methods. The cost of producing corn relative to that of wheat was further favored by lower wages of unskilled labor, lower costs of horse power, and higher prices of machinery than in the United States. Moreover, the peak of labor requirement in Argentine agriculture at that time was definitely at wheat harvest. At the corn harvest, labor was again cheap. According to the computations by Martinez, an Argentine statistician,⁴⁴ in 1910-14 the average cost per hectare of corn delivered in sacks to the railway station was 35.06 paper pesos as against 37.85 paper pesos for wheat.⁴⁵ Owing to the high cost of labor at wheat harvest, the ratio between Martinez's costs ought probably to be treated as a ratio between costs of two grains of which one, wheat, is produced at higher rates for labor and the other, corn, is produced at lower rates.

So far as cultural practices are concerned, no fundamental changes appear to have occurred in Argentine corn produc-

⁴³ So far as concerns corn, eastern North Dakota (data for North Dakota also are included in Table 15) represents a somewhat more intensive type of production.

⁴⁴ Wilhelm Schmidt-Klugwist and Christian Grotewold, *Argentinien in geographischer, geschichtlicher und wirtschaftlicher Beziehung* (2d ed., Hannover, 1919).

⁴⁵ So little cultivating of corn was done that its cost was offset by the saving on the cost of seed. The cost of harvesting and shelling the twice as heavy corn crop was 12.97 paper pesos per quintal as against 16.00 paper pesos expended on harvesting wheat. The saving on harvesting corn more than compensated for the higher cost of hauling the much larger corn crop. Sacks used for corn were said to be so cheap that twice as many sacks needed for it cost less than the better sacks for wheat.

tion since Martinez made his computation. The land for corn is probably prepared a little more thoroughly now, but this may be true of wheat as well. Also, corn is possibly cultivated more carefully now, but no manure is applied. Yet the mere fact of the large increase in the Argentine corn acreage relative to that of wheat (and of all other crops) since prewar years⁴⁶ has tended to make its production relatively more expensive. The labor situation is now not quite so favorable for corn as it was, also because widespread use of the combine has considerably relieved the pressure of work at the wheat harvest.⁴⁷ Unlike the costs computed by Martinez, the labor costs officially computed for recent years may be more or less close to costs at uniform rates. Most other items except the charge for land use have probably also been computed at approximately uniform rates. We are unable to check Martinez's figures on the cost of sacks. Now, in any case, old sacks cost about three-quarters as much as new sacks. Assuming that new sacks are used for wheat and old sacks for corn, twice as many sacks for corn involve an outlay 50 per cent in excess of that on wheat sacks.

According to data in Table 20, the per-acre cost of corn, excluding the charge for land use, in the three most important corn regions—northern Buenos Aires, southern Santa Fé, and central Córdoba—was in 1933-34 20.2, 30.6, and 38.0 per cent, respectively, higher than the per-acre cost of wheat. The

⁴⁶ In 1910-14 the acreage in wheat was about 75 per cent larger than that of corn, whereas in recent years the excess of wheat acreage was only about 35 per cent.

⁴⁷ But the labor situation during harvest time still seems to favor corn in Argentina. Climatic conditions allow much more time for the corn harvest than in the Corn Belt. Moreover, workers occupied in harvesting small grains, such as tractor drivers and operators of headers and combines, are still relatively scarce in Argentina and receive much higher wages than common farm laborers. In 1933-34 the average day wages (in paper pesos) in the province of Buenos Aires were as follows (Argentina, Ministerio de agricultura de la nación, dirección de economía rural y estadística, *Anuario Agropecuario*, Año 1935, pp. 496-97):

Tractor driver	5.30
Driver of binder or header.....	4.95
Driver of combine	6.45
Man in charge of thresher.....	8.65
Fireman at thresher	4.80
Farm hand	3.40-3.50

TABLE 20.—COSTS OF PRODUCING CORN AND WHEAT IN SPECIFIED REGIONS OF ARGENTINA IN SOME DETAIL IN 1933-34*

(Paper pesos per hectare)

Item	Northern Buenos Aires		Southern Santa Fé		Central Córdoba	
	Corn	Wheat	Corn	Wheat	Corn	Wheat
Use of land.....	24.87	21.31	24.83	19.24	14.81	11.58
Interest	3.55	4.95	3.32	5.86	2.79	5.64
Depreciation	5.32	6.62	5.07	7.55	4.79	6.97
Gastos de producción	37.47	29.56	36.32	21.96	30.40	17.55
Sacks and haulage.....	13.39	8.57	13.14	8.92	11.90	5.99
Total, including land use....	84.60	71.01	82.68	63.53	64.69	47.73
Total, not including land use	59.73	49.70	57.85	44.29	49.88	36.15
Yield per hectare in quintals	24.50	12.50	24.50	13.00	23.00	9.50

* Argentina, Ministerio de agricultura de la nación, dirección de economía rural y estadística, *Anuario Agropecuario, Año 1935*, pp. 524-27. For comments, see footnotes to Table 21. Unfortunately the detailed data are in a rather summarized form.

differences are reduced to 12.7, 26.4, and 25.9 per cent, if the costs of sacks and haulage are excluded. Such differences in cost must be appraised as moderate, if the high yield of corn relative to wheat is considered.⁴⁸ In regions with a smaller proportion of land in corn acreage than that observed in the three regions mentioned (Table 21), the per-acre cost of corn, excluding the charge for land use and sacks, exceeds the cost of wheat only slightly or is approximately equal to it. In La Pampa the per-acre cost of corn is less on the basis of both total costs and costs excluding land rent.⁴⁹

Argentine regions where the land is kept in grain only long enough to prepare the land for alfalfa again⁵⁰ do not

⁴⁸ In central Córdoba, the yield of corn was almost two and one-half times the yield of wheat.

⁴⁹ In comparing the data for Argentina with those for Nebraska or Kansas, the facts should be kept in mind that the difference between the yields of corn and wheat is much larger in Argentina, and that corn is handled in sacks in Argentina and in bulk in most of the United States. The latter fact carries particular weight, since in the years for which Argentine cost data are given in Tables 20 and 21 the cost of sacks represented a larger proportion of total costs than usual. All these circumstances evidently tend to make the relative per-acre cost of corn appear higher in Argentina than, for example, in Nebraska. Their effect on the relationships between per-acre costs may have more than offset the opposite effect of factors favoring Argentine corn.

⁵⁰ A large proportion of Argentine corn is grown in regions very favorable for alfalfa.

TABLE 21.—COSTS OF PRODUCING CORN AND WHEAT IN ARGENTINA AT AVERAGE YIELDS BY REGIONS, 1933-34*

District	Cost per hectare (paper pesos)						Yield (quintals per hectare)		Cost per quintal (paper pesos)	
	Operating*		Use of land		Total costs		Corn	Wheat	Corn	Wheat
	Corn	Wheat	Corn	Wheat	Corn	Wheat				
<i>Buenos Aires</i>										
Northern	46.43	41.34	24.87	21.31	84.60	71.01	24.50	12.50	3.45	5.68
West central.....	31.34	28.29	12.26	11.08	52.87	46.65	17.50	11.00	3.02	4.24
Southwestern .....	....	24.88	....	6.33	....	35.63	....	6.50	....	5.48
Southern .....	....	29.40	....	9.55	....	46.23	....	10.00	....	4.62
South central.....	30.76	....	10.99	....	51.27	....	17.50	....	2.93	....
Average	41.75	29.13	20.92	10.69	74.85	46.71	22.39	10.05	3.34	4.65
<i>Santa Fé</i>										
North central.....	....	28.72	....	10.51	....	45.60	....	9.50	....	4.80
Central	37.78	....	17.90	....	66.64	....	20.00	....	3.33	....
Southern	44.71	35.37	24.83	19.24	82.68	63.53	24.50	13.00	3.37	4.89
Average	43.66	32.89	23.78	15.98	80.25	56.84	23.82	11.69	3.37	4.86
<i>Córdoba</i>										
Central	37.98	30.16	14.81	11.58	64.69	47.73	23.00	9.50	2.81	5.02
Southern	31.56	26.19	10.53	8.55	50.91	40.32	17.50	9.00	2.91	4.48
Average	36.10	29.15	13.56	10.81	60.66	45.85	21.39	9.37	2.84	4.89
<i>Entre Ríos</i>										
Eastern	30.99	29.28	10.85	9.24	49.79	44.10	15.00	9.00	3.32	4.90
Western .....	....	28.67	....	9.24	....	43.67	....	9.50	....	4.60
Northern	26.13	....	9.81	....	43.26	....	15.00	....	2.88	....
Average	28.20	28.96	10.25	9.24	46.04	43.87	15.00	9.26	3.07	4.74
<i>La Pampa</i>										
Average	16.91	19.16	3.98	4.30	24.49	26.99	7.00	5.50	3.50	4.91
<i>Average</i>	40.66	29.02	19.92	10.98	72.55	46.41	22.42	9.71	3.24	4.78

COST PER ACRE

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* *Anuario Agropecuario, Año 1935*, pp. 524-27. The yields are those considered normal for each district rather than those actually harvested. The higher charge on corn for land use may be a reflection of the larger profit from corn growing.

* Includes the items interest, depreciation, and "gastos de producción" of the original data. Gastos de producción include costs other than interest, depreciation, sacks and haulage, and land rent.

belong to those where a regular rotation of different grains seems to be practiced. In such regions cropping of one grain (especially corn) year after year hardly affects yields materially. Hence in selecting the grain to be grown in rotation with alfalfa, the farmer does not need to give serious consideration to anything save the relation between direct costs involved in the production of the different grains and their prices.

In Argentine regions unfavorable to alfalfa, corn is a desirable member of the rotation in conjunction with wheat, owing to its favorable effect on wheat yields. The climatic and labor difficulties encountered in a large portion of the United States in having winter wheat follow corn are not present in Argentina. Corn can therefore claim some remuneration for its favorable effect on yields of wheat outside of the alfalfa regions, and the per-acre cost of corn production becomes relatively less than officially computed, while that of wheat is enlarged correspondingly.⁵¹

The method of corn production in most Danubian countries is rather extensive, and wages are much lower than even in Argentina. But harvesting corn is relatively expensive, since all stover is saved. The per-acre costs directly involved in corn production may thus slightly exceed those of wheat in the Danubian countries. However, except in the north, the frost-free period usually leaves sufficient time to prepare a satisfactory seedbed for winter wheat, which is the common successor of corn in the rotation, and there is probably enough labor to harvest the whole crop in time. If the favorable effect of corn on yields of wheat is considered, the per-acre costs of both grains may be about equal, or it may even cost slightly less to grow an acre of corn than an acre of wheat.

In the Corn Belt.—The methods of producing corn in the

⁵¹ C. F. Jones ("Agricultural Regions of South America," *Economic Geography*, January 1928, IV, 12) writes on the situation in Argentina: ". . . corn and wheat are permanently associated; the two are rotated. The wheat crop benefits considerably by the constant weeding and clearing which corn requires." But there is also evidence that the advantages of rotations are not fully realized in Argentina, and a single crop is grown for several years on the same land before a shift takes place.

TABLE 22.—ITEMIZED COSTS OF PRODUCING CORN, WINTER WHEAT, AND SPRING OATS ON REPORTING FARMS IN IOWA AND ILLINOIS, 1923*

(Cost in dollars per acre; yield in cents per acre)

Item	Iowa			Illinois		
	Corn	Wheat	Oats	Corn	Wheat	Oats
Prepare and plant.....	3.70	3.00	1.95	3.76	3.54	2.16
Cultivate	2.66	.....	.....	2.63	.....	.....
Harvest and thresh.....	3.38	4.13	3.82	3.04	4.21	3.77
Marketing	2.12	1.29	1.24	1.81	1.03	1.00
Miscellaneous labor .....	.09	.17	.15	.10	.13	.19
Commercial fertilizer .....	.03	.08	.01	.20	.47	.16
Manure	2.16	.61	.42	1.78	.88	.32
Seed .....	.45	1.74	1.32	.40	1.58	1.23
Miscellaneous costs	2.13	2.27	2.23	1.87	1.91	2.04
Land rent	8.57	7.51	7.60	6.27	6.65	6.73
Gross cost	25.29	20.80	18.74	21.86	20.40	17.60
Credit per acre (straw).....	1.20	1.15	1.51	1.18	1.24	1.72
Net cost	24.09	19.65	17.23	20.68	19.16	15.88
Yield on reporting farms....	26	11	13	23	12	12

* *Agriculture Yearbook, 1924, p. 1136. See comment in footnote to Table 16.*

western Corn Belt of the United States are moderately intensive; moderate amounts of manure are applied, and rotation hay is grown. Yet the stalks are left in the field uncut. According to official data, the gross per-acre cost of corn in Iowa on the average of 1922-31 exceeded that of wheat by 17.5 per cent (Table 16, p. 359).⁵² The official computations for Illinois and Indiana indicate even smaller differences;⁵³ but the data for Iowa, the more uniform state, probably deserve greater attention.

Detailed data in Table 22 show that, in addition to the whole cost of cultivation, corn bears larger costs than wheat

⁵² The computations of J. A. Hopkins, Jr., for Iowa County, Iowa (*op. cit.*, pp. 288, 301) yield about the same ratio between the per-acre costs of corn and wheat as the computations of the Bureau of Agricultural Economics for the whole state.

⁵³ The average gross cost per acre in Indiana in 1922-31 was \$24.55 for corn and \$22.79 for wheat. Data for Illinois in Table 16.

for land preparation and manure. The lower costs on seed and harvesting are insufficient to offset these extra costs. Without doubt, corn was charged considerably higher per-hour rates for labor used in harvesting than wheat. The higher charge for land rent in Iowa as officially ascertained is likely to reflect, at least in large degree, the higher profits of corn growing. Both differences should be eliminated if costs at uniform rates are desired. The per-acre cost of wheat must furthermore be raised to provide sufficiently for losses due to winterkilling. With corrections of the charges for land use and winterkilling, the difference in per-acre costs of corn and wheat in Iowa would be sensibly less than that officially computed.⁵⁴

The official computations of the cost of producing corn in Iowa and Illinois presumably pertain primarily to corn picked with the stalks left in the field uncut. Since the data are averages for 1922-31, the picking of ear-corn was probably almost exclusively by hand. Except when wages are very low, machine picking, which is gaining ground in the Corn Belt, reduces the cost of picking corn in that area considerably.⁵⁵ But, provided the straw is not saved, harvesting of wheat in the Corn Belt is reduced even more by use of the combine, and the recently introduced small combine has become quite at home there in a short time.

If the official computations were for corn hogged down, the per-acre cost (exclusive of land rent or with an equal land rent) of corn and wheat would be practically the same in Iowa, while in Illinois the cost of wheat would be the higher. A computation for silaged corn or for corn harvested with the stover shredded, on the other hand, would increase the differ-

⁵⁴ The difference in per-acre cost would be even smaller if the difference in rates of harvest labor were eliminated; but such elimination is not attempted in our final computations.

⁵⁵ According to P. E. Johnston and K. H. Myers, *Harvesting the Corn Crop in Illinois* (Illinois Agr. Exp. Sta. Bull. 373, September 1931), p. 405, husking by hand cost \$5.11 per acre in Illinois in 1928 and 1929, as against \$2.98 for corn husked by two-row pickers. The cost of machine husking, moreover, was somewhat overestimated by the authors.

ence between the per-acre costs of corn and wheat considerably beyond the amounts officially computed.⁵⁶

From the discussion earlier in this chapter it is evident that any ratio between the cost of wheat and corn in the Corn Belt is almost meaningless, unless the position occupied by each grain in the rotations is specified. As with the ratios between the per-acre costs of winter wheat and oats, the ratios between the per-acre costs of winter wheat and corn depend greatly on the possibility of having winter wheat follow corn in rotations.

It has been shown that difficulties are met with in growing winter wheat after corn harvested from standing stalk even as far south as Kansas. The difficulties are naturally even greater in the Corn Belt. Removing stalks and ears together leaves more time for preparing the seedbed for winter wheat; but the practice is rather expensive, and is justified by the value of the stover only in the eastern Corn Belt and still farther east where corn stover is less abundant and feed prices are generally higher. Harvesting corn for silage is an even speedier way to clear fields of the corn crop, but the procedure is limited by the size of the silos and the requirements for silage. In the northernmost portion of the Corn Belt, moreover, winter wheat cannot follow corn, even if the corn is shocked or silaged.

The difficulties of having winter wheat follow corn are obviously larger the more land is occupied by corn. In most of Iowa, Illinois, and Indiana (see Chart 30, p. 255, for the situation in central Illinois), the usual time of harvesting corn is after the winter wheat has already been sown. The same situation is found in the northern portions of Ohio and Pennsylvania. In central portions of these two states farmers apparently succeed in seeding a portion of wheat on corn land cleared by shocking in addition to that harvested for silage. To avoid postponement of the date of seeding beyond the

⁵⁶ According to J. A. Hopkins, Jr. (*op. cit.*, p. 294), the additional cost of shredding the stover amounted to \$7-8 per acre in Iowa County on the average in 1925-27.

optimum, some winter wheat in Ohio also is sown in the standing corn, without any preparation of the soil. One requirement of successful wheat growing—thorough preparation of the land—is obviously sacrificed for another—timeliness of seeding.⁵⁷ The farther to the south the larger is the proportion of wheat which can follow corn in the rotations.

Where neither way of following corn with winter wheat proves practicable, the only means of growing winter wheat in the same rotation with corn is to place a spring grain between them. The typical rotations of the heart of the Corn Belt (corn-oats-hay, corn-corn-oats-hay, corn-oats, and the like) become one year longer. But if it were desirable that wheat under the same conditions should return to the same land more frequently than once every four or five years, a fundamental rearrangement of the whole cropping system would be inevitable. To have some 40 per cent of the acreage in winter wheat, corn would have to be nearly eliminated.

Thus we have to distinguish several ratios between per-acre costs of winter wheat and corn. The ratios between the officially computed costs, with corrections suggested above, may perhaps be valid for the rotation of corn-winter wheat in the southern Corn Belt where winter wheat can follow corn without great difficulties. But even there the time interval is insufficient for very thorough preparation of the land, and corn is unlikely to exert a beneficial effect on the yield of wheat. It may be necessary only to charge wheat for being a less desirable preceding crop than oats. However, in the important rotations corn-small grain-hay or corn-corn-small grain-hay, wheat may claim a credit for its service as a cover crop.

No material change in the cost ratio will probably occur if we turn from the rotation corn-winter wheat to the rotation corn-oats-winter wheat. The adverse effect of having winter

⁵⁷ This practice is also used on a large portion of winter wheat following corn in rotations in type-of-farming area 12 of Colorado—see Byron Hunter and others, *Type of Farming Areas in Colorado* (Colorado Agr. Exp. Sta. Bull. 418, September 1935), p. 109; but it seems to have no prospect of becoming general.

wheat in the rotation would again be limited to the possibility of corn yielding slightly less after wheat than after oats. However, in the rotations corn-oats-hay, or corn-corn-oats-hay, more typical in the heart of the Corn Belt, the inclusion of winter wheat in the first rotation or the exchange of one corn for winter wheat in the second (with a shift of oats to the second place) would involve the possibility of an adverse effect of winter wheat not only on the yield of the succeeding crop (hay), but through this medium on the yields of all crops grown in the rotation. Moreover, oats rather than wheat should be credited for the service as a cover crop, though wheat performs this function. The adverse effect of winter wheat on the whole rotation will be even greater if corn is eliminated entirely, for a row crop is probably rather indispensable for a good rotation, not only from the point of view of yields but also from that of a good seasonal distribution of labor and power work. The elimination of corn, it is true, makes it possible to dispense also with the oats crop. All possible combinations and their implications cannot be discussed here.

The reader will not be surprised that the ratios between the cost of producing corn and wheat in the Corn Belt have been discussed first, although the acreage in oats in the Corn Belt is several times as large as the acreage in wheat. Wheat, though defeated by corn in the region, is nevertheless its only serious potential competitor among the grains. On the other hand, there is practically no competition between corn and oats. According to the official computations in Table 16 (p. 359), the gross cost per acre of corn in Iowa and Illinois exceeded that of oats by 31.6 and 29.5 per cent, respectively. With equal charges for land use, these percentages would be reduced to 26.6 and 27.5. These ratios could be used wherever hay does not follow oats in rotation, so that no credit need be given to oats for the service as a cover crop that we hesitate to estimate; but oats would have to be charged somewhat more for manure than is done in official computations, while corn should be credited for its superiority as a

preceding crop. These costs could be used as those at uniform rates with the understanding that the rates for labor were higher for corn than for oats.

Under intensive methods.—To find in the United States a really large difference between the per-acre costs of corn and small grains as a regular occurrence, one must turn to conditions in the northeast where corn is produced very intensively and every bit of stover (and straw) is saved. On page 361 the average per-acre costs of small grains on New York accounting farms in 1914–31 were quoted. They varied from \$34.60 for oats to \$39.40 for wheat. The comparable figure for corn was approximately \$56.00.⁵⁸ Thus the per-acre cost of corn was about 40 per cent higher than that of wheat.⁵⁹ Some charge in favor of corn, it is true, might be needed occasionally for its beneficial effect on the yield of crops following it in the rotation.

⁵⁸ The authors of the Cornell study use as a comparable figure the cost of producing corn for grain, which in the period specified was \$63.60. The figure given in the text is that of an acre of corn for silage. The higher cost of corn harvested for grain resulted mainly from the very small acreage of such corn per farm.

⁵⁹ The principal additional per-acre costs of producing corn for silage as compared with those of wheat on the average in 1927–30 were the higher outlay on lime, manure, and fertilizer (\$14.08 on corn and only \$7.95 on wheat); on labor and power for growing (15.8 man hours, 23 horse hours, and 3.5 tractor hours on corn as against 7.4, 10.3, and 3.0 hours, respectively, on wheat); and on harvesting (\$14.65 on corn and only \$7.28 on wheat).

CHAPTER XVI

COST PER CENTAL

It was shown in chapter xv that in general the per-acre cost of producing the different small grains on stubble land does not vary much within any given area. Differences in yield are therefore usually the principal factor determining the differences in the per-cental cost of producing these grains.

So far as there are differences in per-acre costs of producing small grains, wheat is the most costly to produce, except in some regions where very extensive methods are practiced. The disadvantage of wheat in per-acre cost relative to other small grains tends to increase as the intensity of production rises. Wheat, moreover, is also the grain which usually ranks low in yielding power. Hence it is only under exceptional conditions that wheat is cheaper to produce per cental than any of the other small grains.

The lower per-acre costs of wheat as compared to the per-acre costs of certain coarse small grains are observed in certain drier regions which are either too cold for winter wheat or warm enough for winter barley. But these are exactly the regions in which wheat, even grown on suitable lands, makes the worst showing in yield among small grains. On the other hand, the most important among the regions in which wheat yields are relatively best are those which are warm enough for winter wheat but too cold for winter barley and which practice very intensive methods of crop production. Under these conditions, winter wheat frequently outyields all other small grains. The cost per acre, nevertheless, so much exceeds the per-acre costs of the other small grains there, that wheat remains the most expensive grain to produce per cental. But its disadvantage in cost per cental in these regions is usually materially less than in the drier regions too cold for winter wheat or warm enough for winter barley. The improvement in relative cost per cental of wheat from the one type of

region to the other is largest relative to the cost of barley and smallest relative to the cost of oats. In very moist climates the per-cental cost of wheat relative to that of oats may even be more unfavorable for wheat than it is in drier regions growing spring wheat.

Fall-sown barley is relatively the best yielder in sufficiently warm regions with a small annual precipitation that comes mostly in the winter. This superiority is over any other grain rather than merely the grains studied here. Fall-sown barley on suitable soil mostly outyields any other fall-sown small grain also in moister climate, and spring barley behaves likewise in drier regions too cold for winter wheat. Per-acre costs of barley grown in drier regions, however, exceed those of the other small grains at most to the extent that harvesting and marketing a large crop costs more than harvesting and marketing a small crop. Hence in sufficiently warm regions with small annual precipitation falling primarily in the winter, such as are found within regions with Mediterranean climate, fall-sown barley is the cheapest grain to produce. Spring barley is in the same position in drier regions too cold for winter wheat and corn. There are some exceptions, it is true, for both fall-sown and spring barley.

The material advantage of barley in yield over the other small grains declines sharply from drier to moister areas; but the ratio between the per-acre costs of barley does not alter in the opposite direction proportionately, and sometimes even becomes less favorable for barley. Hence the cost per cental is less favorable for barley in moister than in drier areas. The change is particularly apparent, if the position of barley is compared with that of oats, the principal competitor of barley for acreage in many areas. While barley usually is cheaper to produce per cental than oats in drier regions, the opposite is true in moister areas. The ratio between costs per cental of barley and oats should be especially unfavorable to barley in moister areas practicing extensive methods of production, for the superior response to cultural practices helps

barley against oats in moister areas where intensive methods of crop production are used. There are, however, offsetting factors which bring it about that barley produced by intensive methods may even cost *substantially* more per cental than oats. Many places in the complicated rotations frequently practiced there are suitable for oats but are not adapted to the more exacting barley. The fact that much barley is grown for malting purposes is another such factor. The per-cental cost of producing two-row malting barley, which is grown almost wholly in moister regions, in fact tends to be very close to the per-cental cost of wheat.

Oats are decidedly the best yielder and also the cheapest grain to produce per cental among small grains on soils poor in nutrients in readily available form and strongly acid, in moister areas also on heavy soils, and in notably moist areas on almost any soil. Rye comes next under all these conditions. It is the best yielder and the cheapest grain to produce per cental among small grains on light soils (except perhaps those that are heavily fertilized) and on very light soils—in both cases except where corn can be grown.

Except under extremely unfavorable climatic conditions, the large superiority of corn in yield suffices to offset its high per-acre cost. Corn yields almost twice as much as wheat and 60 to 75 per cent more than any other small grain in regions satisfying its specific requirements as to moisture and temperature and using rather extensive cultural practices, if the extensiveness does not go so far as to exclude sufficient inter-row cultivation of corn. The per-acre cost of corn, however, under these conditions is unlikely to exceed the per-acre cost of wheat by more than 10–15 per cent and the per-acre cost of any other small grain by more than 20–25 per cent. The per-cental cost of corn is therefore considerably less than the cost of any small grain in climatic conditions favorable to corn.

A moderate amount of intensity, for example, in the form of application of some manure or of the growing of a legumi-

nous crop before corn, is unlikely to affect the ratios between yields appreciably against corn; for with temperature and soil adequate to corn, it can be expected to respond to these practices much more strongly than the other grains. The ratio of per-acre costs, it is true, also may be altered somewhat to the disadvantage of corn. Corn nevertheless is likely to retain almost all its advantage in cost per cental. But if the intensity of production reaches such a stage that the land becomes merely the locus of growth, providing water and warmth but little else, corn inevitably loses its advantage in cost per cental, except that resulting from its ability to produce a larger yield with larger supplies of nutrients.

The ratios between yields of corn and of small grains become less favorable for corn also as we move from moister to drier regions, but simultaneously the ratios between the per-acre costs alter in favor of corn. The ratios between costs per cental in regions with moisture moderately insufficient for corn may still be almost as favorable to corn as the ratios in regions which have a climate ideal for corn and practice moderately intensive methods of crop production. The ratios between the per-cental cost of corn and small grains may be considerably more favorable to corn than they are in regions with sufficient moisture practicing very intensive methods of crop production, even where the supply of moisture is far less than needed for the best yields of corn. For the drier regions are likely to have per-acre costs of corn approximately equaling those of wheat, while in the regions of intensive agriculture the per-acre cost of corn may be the larger by as much as 40 per cent.

SMALL GRAINS

In drier regions.—Let us again begin with the small grains and take up first the situation in the Prairie Provinces of Canada, where the grains are grown under conditions fairly uniform as to soil and climate and where, moreover, the situation is rather simple because of the small number of crops in

the rotations. Table 23 shows an official computation of average costs in 1923 and 1924 on reporting farms, and average yields on all farms in that region.

The average per-acre cost of production of oats in these

TABLE 23.—COSTS OF PRODUCING SMALL GRAINS ON REPORTING FARMS IN THE PRAIRIE PROVINCES, 1923 AND 1924*
(Cost in dollars; yield in centals per acre)

Item	Year	After stubble				After fallow
		Oats	Barley	Rye	Spring wheat	Spring wheat
PER ACRE						
Total cost	1923	14.84	13.90	12.77	14.00	18.06
	1924	12.85	12.64	12.64	12.60	15.73
	Av.	13.85	13.27	12.70	13.30	16.90
Land rent	1923	2.89	2.84	2.79	2.93	3.86
	1924	2.64	2.71	2.75	2.73	3.50
	Av.	2.76	2.78	2.77	2.83	3.68
Cost, excluding land rent	1923	11.95	11.06	9.98	11.07	14.20
	1924	10.21	9.93	9.89	9.87	12.23
	Av.	11.08	10.50	9.94	10.47	13.22
Yield on reporting farms	1923	15.3	14.6	10.6	10.9	14.6
	1924	10.3	10.9	10.2	7.3	10.0
	Av.	12.8	12.8	10.4	9.1	12.3
Yield in Prairie Provinces	1923	14.3	14.5	9.0		12.3
	1924	9.3	11.7	8.3		7.6
	Av.	11.8	13.1	8.6		10.0
	Av. 1927-36	8.4	9.3	6.3		8.4
PER CENTAL						
Excluding land rent	1923	.78	.76	.94	1.02	.97
	1924	.99	.91	.97	1.35	1.22
	Av.	.88	.84	.96	1.18	1.10
Including land rent	1923	.97	.95	1.20	1.28	1.24
	1924	1.25	1.16	1.24	1.73	1.57
	Av.	1.11	1.06	1.22	1.50	1.40

* Canada, Dominion Bureau of Statistics, *Cost of Grain Production in Canada, 1923* (partly reprinted from the *Monthly Bulletin of Agricultural Statistics*, June 1924), 1924; *Monthly Bulletin of Agricultural Statistics*, August 1925, XVIII, 250. Data on yields from *Reports of the Grain Trade of Canada*. See also footnote to Table 14 (p. 351).

years was 4 per cent higher than the cost of spring wheat after stubble; the per-acre cost of barley was as high as that of stubble wheat; the cost of an acre of rye was 5 per cent lower. Barley and oats on the reporting farms yielded on the average 41 per cent more than wheat after stubble, and the yield of rye was 14 per cent more. The result was that the cost of production (including land rent) per cental of spring wheat was 41, 35, and 23 per cent higher than the costs per cental of producing barley, oats, and rye, respectively. With slight revisions (45, 30, and 20 per cent, respectively), these ratios are accepted as representing ratios between costs of crops calculated at uniform rates. The lengthy reasoning is presented below.

According to official computations, a cental of wheat after fallow was more expensive to produce than a cental of barley, oats, and rye on stubble by 32, 26, and 15 per cent, respectively. If we assume that 45 per cent of the wheat was grown after fallow,¹ the average cost of production per cental of all wheat on reporting farms exceeded the per-cental costs of barley, oats, and rye by 36, 31, and 19 per cent, respectively. But the use of data on the cost of producing wheat on fallowed land is hardly permissible. The reported per-acre cost of wheat after fallow seems to be rather low as compared with the cost of wheat and coarse grains grown on stubble (see footnote in Table 14, p. 351). And the data on page 329 show that in the northern Great Plains of the United States, barley and oats respond to fallowing as well as wheat, in both absolute and percentage terms. The same must be assumed for the Prairie Provinces. Hence barley and oats would also be cheaper to produce on the Canadian prairies if they were grown on fallow. A proper comparison of costs in the Prairie Provinces ought apparently to be limited to the use of data pertaining to costs on stubble land.

For our purpose it is irrelevant whether the average costs on all farms are higher or lower than those on reporting farms.

¹ Approximately the percentage for the whole of the Prairie Provinces in 1923 and 1924.

It is, however, necessary to guard against differences in the ratios between costs of production of different grains on reporting and on all farms. A check seems to be particularly important with regard to the extent to which the ratios between yields of different grains obtained on reporting farms in 1923 and 1924 coincide with the ratios between long-time averages for all farms. To make this comparison, it is necessary to know the average yields of wheat on fallow and on stubble land on all farms of the Prairie Provinces. Unfortunately, there is only a single official figure on the yield of wheat, covering both stubble and fallow wheat. One can only be rather arbitrary in splitting this single yield figure into yield from fallow and yield from stubble land.

On the assumptions that on the average in 1927-36, 55 per cent of the wheat was grown on fallow land,² and that wheat on fallow yielded 40 per cent more than wheat on stubble,³ yields are indicated of 9.7 centals per acre for fallowed wheat and of 6.9 centals for wheat grown on stubble land. If the average yields of coarse grains in the decade 1927-36 are compared with the average yield of wheat from stubble land thus computed, the yields of barley and oats are higher than the yield of wheat on stubble by 35 and 22 per cent. This compares with 41 per cent for each grain on the farms reporting costs in 1923 and 1924. If splitting the single

² This figure was reached by summing up the land in summer fallow and new breaking as officially reported (interpolating the figures for Alberta for a few years), subtracting the acreage in flax, multiplying the remainder by 100, and dividing the resultant figure by the acreage in all wheat.

³ Experiments conducted for 15 years on experiment stations at Indian Head and Scott, Sask., and Lacombe, Alta., indicate that in the rotation summer fallow-wheat-wheat, first-year wheat yielded 46 per cent more than second-year wheat. E. S. Hopkins and S. Barnes, *Crop Rotations and Soil Management for the Prairie Provinces* (Canada Dept. Agr. Bull. 98, New Series, 1928), p. 9. It is somewhat doubtful, however, whether the difference is as high between average yields on fallow and on stubble land on all farms. The percentage of the land in fallow in the Prairie Provinces would probably be materially larger than it actually is, if the additional yield from fallow land were much higher than some 35 per cent; for the cost per acre of fallowed wheat on reporting farms in 1923 and 1924 would have exceeded the cost of wheat on stubble by somewhat less than 33 per cent even if the charge for land use on fallowed wheat were twice as large as the same charge for wheat on stubble. Finally, on the average for 1923 and 1924, wheat after fallow on reporting farms yielded 35 per cent more than did wheat after stubble.

yield figure for wheat has been made correctly, the average yield of rye on all farms in the Prairie Provinces was 9 per cent less than the yield of wheat on stubble, while on reporting farms the yield of rye was 14 per cent higher. However, yields during the preceding decade (1917-26) indicate only for oats and rye less favorable ratios to yields of wheat on stubble than those obtained on the reporting farms on the average of 1923 and 1924. The yields of those two grains exceeded the yield of spring wheat after stubble by 30 and 7 per cent, respectively, rather than by 41 and 14 per cent as on the cost-reporting farms in 1923 and 1924. The ratio between yields of barley and wheat in 1917-26 was even somewhat more favorable to barley than it was on the reporting farms in 1923 and 1924, the yield of barley exceeding that of wheat after stubble by 45 rather than by 41 per cent.⁴

Thus the analysis of yields on all farms over a longer period apparently calls for no revision of the ratio between cost per cental of barley and wheat computed from data of reporting farms for 1923 and 1924. But some revision is necessary owing to the favorable effect of barley on the succeeding crop. The increase of the percentage by which the officially computed cost per cental of wheat exceeds that of barley from 41 to 45 should make ample provision for this effect under Canadian conditions.⁵

On the other hand, the ratios between yields of oats and rye as obtained on all farms indicate the necessity of a revision of the ratios between costs per cental of these grains and wheat; in the case of rye the needed revision seems to be large. The officially computed percentages by which the cost per cental of wheat exceeded that of oats was reduced by 5 per cent. That

⁴ In subdividing the yield of all wheat officially given for 1917-26 into yield from stubble and yield from fallow, the same procedure was followed as was used with regard to the yields in the decade 1927-36, except that the proportion of the acreage in wheat grown after fallow was assumed to have been 45 rather than 55 per cent of the total. This division of the single yield given in official statistics resulted in a yield of 10.9 centals of wheat after fallow and 7.8 centals of wheat after stubble.

⁵ See p. 272. The provision seems to be ample, since barley mostly precedes fallow. No adjustment of the costs of oats and rye for the effect of these crops on the yields of succeeding crops seems worth while.

for rye was reduced by only 3 per cent; for the less favorable ratio between the yields of rye and wheat on all farms as compared with the yields on reporting farms may have been caused by the facts that, on the average of all farms, less valuable land was used for rye than for wheat,⁶ and that preparation of the land for rye was generally less thorough than was indicated by the cost data from reporting farms.⁷

The actual cost ratios are usually somewhat more favorable for coarse grains than cost ratios at uniform rates as accepted above, because these grains are grown in small acreages. As minor crops, coarse grains ought to be charged somewhat lower rates per hour for labor, power, and machinery. Under such conditions, oats may also be entitled to a small remuneration for being a better preceding crop than wheat.⁸

It is a rather general assumption that wheat production in Manitoba is relatively less profitable than in the other two western provinces of Canada. Data on the cost of production per cental in Table 24 also point in this direction. The ratios between average yields are somewhat less favorable for wheat in Manitoba than in the other two provinces,⁹ and there appears to be no compensation for this disadvantage in more favorable ratios between per-acre costs.

There are regions in the Canadian prairie other than Manitoba where the ratios between per-cental costs of wheat and coarse grains are less favorable for wheat than they are for the Prairie Provinces as a whole. This is particularly true of the north, where the frost-free period is rather short even for

⁶ Land of approximately the same quality was probably used on reporting farms for rye and for all other grains grown on stubble, as is indicated by the practically equal charge for land use.

⁷ For neither grain was an adjustment of the official figures made for changes brought about by the combine.

⁸ Produced in small quantities, these grains may also obtain a somewhat greater advantage than wheat from use of the combine, which is not considered in our computation.

⁹ The difference in the yield ratios was slight in 1927-36, but the figures for 1917-26, a more normal decade with reference to yields, indicate a somewhat larger disadvantage of Manitoba's wheat.

TABLE 24.—COSTS OF PRODUCING SMALL GRAINS ON REPORTING FARMS IN THE PRAIRIE PROVINCES, BY PROVINCES, AVERAGE 1923 AND 1924*

(Cost in dollars; yield in cents per acre)

Item	Province	After stubble				After fallow
		Oats	Barley	Rye	Wheat	Wheat
Cost per acre.....	Manitoba	13.29	12.91	12.24	13.30	16.56
	Saskatchewan	13.95	13.18	12.74	13.12	16.67
	Alberta	15.13	14.76	13.72	14.16	18.46
Yield on reporting farms	Manitoba	12.69	13.56	10.01	8.69	10.73
	Saskatchewan	12.85	12.17	10.22	8.88	12.01
	Alberta	14.49	14.71	11.28	11.57	15.75
Yield in province, average 1927-36..	Manitoba	7.48	9.04	8.25	6.65 ^a	9.31 ^a
	Saskatchewan	7.60	8.51	6.18	6.10 ^b	8.54 ^b
	Alberta	10.64	11.28	5.87	8.44 ^b	11.82 ^b
Cost per cental....	Manitoba	1.06	.95	1.23	1.54	1.57
	Saskatchewan	1.13	1.12	1.24	1.54	1.44
	Alberta	1.06	1.03	1.27	1.30	1.22

* For source, see footnote to Table 23 (p. 389).

^a In computing the yield from fallow and stubble land separately from the single figure officially ascertained, the proportion of wheat grown on fallow land was assumed to have been 60 per cent of the total wheat acreage. Yield on fallow land was assumed to have been higher than on land after stubble by 40 per cent.

^b The same assumptions as indicated in footnote a except that wheat after fallow was assumed to have been 55 per cent of the total wheat acreage.

the earliest varieties of wheat and the prairie soils are replaced by "park land."¹⁰ But the presence of such regions with less favorable cost ratios for wheat indicates that in large portions of the Prairie Provinces the cost ratios are more favorable for wheat than those indicated by the data for the provinces as a whole. In these areas coarse grains can hardly be produced, even in small quantities, at cost ratios more favorable for them than the ratios computed for the provinces as a whole on the assumption of uniform rates.

If the exhaustion of the soil in Manitoba should materially affect the cost of production of wheat as compared with costs of the other small grains, the same effect, though stronger, would be expected in the hard-spring-wheat region of the

¹⁰ The competitive power of wheat in the north is lowered, it is true, more through lower returns per cental than through higher costs per cental.

United States. Yet a comparison of average yields does not point in this direction. Wheat on stubble land in North Dakota in 1927-36 yielded 24 per cent less than in the Prairie Provinces, while yields of rye, barley, and oats were smaller by 14, 22, and 30 per cent, respectively.¹¹ Moreover, the official data on the cost of producing wheat and oats in North Dakota indicate a ratio between per-cental costs of producing wheat and oats more favorable for wheat than in the Prairie Provinces. Similar are the results of our cost computations for wheat and barley. But the differences are small in both cases, and neither crop statistics for whole states nor similar cost-of-production computations warrant conclusions from such differences.

The net cost per acre of oats on reporting farms in North Dakota in 1922-31 (Table 15, p. 355) was 9 per cent less than that of wheat,¹² and the yield of oats was higher by approximately 15 per cent. But in the whole state of North Dakota the yield of oats in the same years averaged only 9 per cent higher than the yield of wheat (it was 13 per cent higher in 1927-36). Thus the per-cental cost of wheat production in the state hardly exceeds that of oats by more than 20 to 25 per cent, according to these data.

Some idea of per-cental costs of producing barley and rye in North Dakota relative to costs of wheat and oats may be gleaned from a comparison of state average yields and from the costs per acre in the Prairie Provinces. Barley in North Dakota, on the average in 1922-31, yielded 30 per cent more than wheat (35 per cent more in 1927-36). Assuming that the net cost of barley was about halfway between the net per-

¹¹ For this computation, the conversion of single-yield figures for all wheat into yields on stubble and yields on fallow was made on the assumption that the acreage in wheat after fallow was 6 per cent of the total in North Dakota and 55 per cent in the Prairie Provinces, and that wheat after fallow in both areas yielded 40 per cent more than wheat after stubble.

¹² The difference would be 2 to 3 per cent less if the per-acre cost of oats were compared with the cost of wheat after stubble rather than with the per-acre cost of all wheat. But this difference need not be considered in computations of costs per cental, since the cost per acre of wheat as computed is increased in about the same proportion as the yield per acre, by including the wheat grown on fallowed land.

acre costs of wheat and oats, the cost of production per cental of wheat is likely to have been about 35 per cent higher than that of barley. If we make due allowance for the beneficial effect of barley as a preceding crop, this percentage will be raised to about 40.

The average yield of rye in North Dakota in the decade 1922-31 was about 5 per cent less than the yield of wheat. The per-acre cost of producing rye may have been some 20 per cent less than the per-acre cost of wheat. Hence the cost per cental of producing wheat was some 20 per cent higher than the per-cental cost of rye. Approximately the same result can be obtained by the following reasoning: Winter rye on the same soils and with the same preparation should out-yield spring wheat by perhaps 15 per cent, while its per-acre cost at uniform rates may be slightly less than that of spring wheat.

Ratios between per-cental costs similar to those computed for the Prairie Provinces and North Dakota may also be accepted for other drier regions, where climate does not permit growth of winter wheat but does not prevent growth of winter rye. However, in eastern Russia including Siberia the yield of barley, and consequently its cost per cental, are not quite so favorable as in the hard-spring-wheat region of North America (p. 268). Winter rye, on the other hand, is in a more favorable position in eastern Russia.¹³

The per-acre cost of barley in California was assumed to be 5 per cent higher than the cost of wheat produced on the same land (p. 357). Barley may be expected to yield some 40 per cent more than wheat. Hence, the cost of barley per cental is approximately 25 per cent less than the per-cental cost of wheat.¹⁴ The ratios between the cost of fall-sown

¹³ Winter rye is a good weed-clearing crop. In North America it is objected to as a crop preceding spring wheat because the admixture of rye to wheat which is difficult to avoid is heavily penalized in grading. In the spring-wheat belt of Russia no objection against admixture of rye to wheat is apparently raised, because the wheat grown after rye is mostly durum from which rye is more easily separated than from common wheat.

¹⁴ The figure is slightly more than 30, if the computation is made on the basis of bulk grain.

barley and fall-sown wheat in French North Africa may be about the same as in California, while the situation seems to be slightly more favorable for wheat on most nonirrigated lands of British India used for production of wheat or barley.

Oats in California cost considerably more to produce per cental than barley—perhaps more than wheat. The same is likely to be true in North Africa and British India.

Our information on Australia (see p. 299) seems to preclude the possibility of applying the findings on the cost of production in California to that country, in spite of the similarity of climatic conditions. The available data on cost of production at the Turretfield demonstration farm in South Australia, it is true, point toward much higher costs of producing wheat than barley; but they are extremely meager and indicate also materially lower cost of producing oats than wheat, though such a relationship apparently does not prevail in California.¹⁵

For the time being, doubt should be entertained whether the per-cental cost ratios between wheat and barley in Australia are as unfavorable to wheat as they are in some other dry regions either unsuitable for winter wheat or suitable also for winter barley. But the cost situation is certainly less unfavorable for wheat in those drier regions where fall-sown wheat survives while barley and oats can be sown only in the spring. Spring-sown small grains particularly handicapped

¹⁵ *Records of Some Department Work*; various issues of the *Journal of the Department of Agriculture of South Australia*.

For a considerable number of years the Turretfield demonstration farm in South Australia was run for the purpose of finding the cheapest way of farming. But barley and oats were harvested for grain in only a few years, and the data on these grains are also not strictly comparable with those of wheat. Probably from considerations of more even distribution of labor and power work, wheat has been grown on fallow land, while barley and oats were grown on stubble. Little land preparation was done for these crops, and less fertilizer was applied than to wheat. Nearly twice as much on the average was expended per acre of wheat than per acre of barley. Yet wheat outyielded barley by only about 25 per cent, and its average cost per cental was about 50 per cent higher. Under similar conditions, the cost per cental of producing wheat was about 40 per cent higher than the cost of oats. The fact that even the price of oats, which in Australia are grown much more widely than feed barley, tends to be about the same as that of wheat (see Melbourne prices in Chart 2, p. 10) impels one to be cautious in using the Turretfield data.

in such regions relative to fall-sown grains; for, with a few exceptions, all of these have hot summers.

As calculated on page 357, the per-acre cost of wheat on reporting farms of Kansas exceeded the cost of oats by approximately 10 per cent, and on the same farms oats slightly out-yielded wheat. Thus the cost per cental of oats on reporting farms ought to be less than the per-cental cost of wheat by somewhat more than 10 per cent. But on the average for the whole state, wheat yielded 7 per cent more than oats in 1911-32. The yield of wheat was higher than the yield of oats in seven of the nine crop-reporting districts. The cost of production of oats at uniform rates in Kansas must therefore be supposed to be approximately as high as that of winter wheat. The cost ratio would of course be sensibly more favorable to oats if the computation reflected the fact that oats are a minor crop and therefore ought to be charged (in Kansas conditions) substantially lower rates for labor, power, and machinery. But the same is true of many other ratios computed here and summarized in Table 25 (p. 411).

Barley yields 10 to 20 per cent more than winter wheat in Kansas, according to official data by crop-reporting districts. Assuming that the per-acre cost of spring barley is slightly higher than that of spring oats, the cost per cental of barley at uniform rates may be some 20 per cent less than that of winter wheat.

The cost per cental of winter rye at uniform rates in Kansas may be less than that of winter wheat by about 10 per cent. A somewhat smaller yield of winter rye must be assumed, but the per-acre cost of winter rye is probably appreciably lower than that of winter wheat because of higher cost of seed for wheat and its larger winterkilling.

The available data on yields obtained in the grain belt of the Pacific Northwest point toward a relative situation approximately as favorable for wheat as in Kansas. The difference in the cost per cental of spring wheat and spring barley in this grain belt is probably more favorable to wheat than

in the Prairie Provinces and North Dakota, and winter wheat costs less to produce than spring wheat. The advantage of spring barley over spring oats with regard to the cost of production per cental is probably not present in the grain belt of the Pacific Northwest states to the same extent as in other drier regions, for the large water-holding capacity of the soil reduces the importance of the earliness of barley. Summer temperatures also are lower in the Pacific Northwest than in Kansas.

In moister regions.—Unfortunately almost all the data presented below are for regions in which winter wheat competes with spring barley and spring oats, while our data for the drier regions pertain primarily to those in which either spring wheat competes with spring barley and spring oats, or fall-sown wheat competes with fall-sown barley and fall-sown oats. The diversity in data makes it impossible definitely to segregate the effect on cost ratios due to the fact that winter wheat usually outyields spring wheat, from the effect on cost ratios due to the facts that wheat yields relatively better than barley and to some extent better than oats in moister than in drier climates, and that intensive methods of crop production improve the competitive position of wheat. But after all, spring barley and spring oats are much more frequently confronted with the competition of winter than spring wheat in moister regions.

In comparing the per-acre costs of winter wheat and spring oats in the Corn Belt on pages 358–60, ratios between the costs in the southern Corn Belt, where winter wheat can follow corn without great difficulties, have been accepted as slightly less favorable for wheat than in the official computations for Iowa and Illinois. On the other hand, the ratio between yields of winter wheat and oats on reporting farms has to be adjusted in favor of wheat, first because the yields on all farms of Iowa and Illinois are relatively less favorable for oats than the yields on reporting farms (Table 16, p. 359), and secondly because yields of oats decline southward more

strongly than those of winter wheat. The cost per cental of oats in the south of the Corn Belt can hardly be less than 85 per cent of the per-cental cost of winter wheat.¹⁶ Northward the ratio in per-cental costs becomes rather rapidly more favorable for oats, owing to the cumulative effect of the relatively more favorable per-acre cost and yield. The comparisons, moreover, are valid only for rotations in which oats and winter wheat are interchangeable in the place after corn. Where winter wheat cannot follow corn, oats should be charged less than winter wheat for the use of land.

The net per-acre cost of barley in the Corn Belt was assumed to be slightly higher than the per-acre cost of oats (p. 360). A cental of barley costs more than a cental of oats at least in proportion to the higher net per-acre cost.

The per-acre cost of wheat (apparently winter wheat) on reporting farms in New York state, on the average in 1914-31, exceeded costs of oats and barley (both apparently spring-sown) by slightly more than 10 per cent (see p. 361). The yields on the same farms and in the same years, in centals per acre, were: wheat, 14; oats, 12; barley, 12.¹⁷ These figures suggest a somewhat lower per-cental cost of wheat than of oats or barley. In view of the small number of reporting farms, especially in the earlier years, it may be preferable not to draw a definite conclusion. Yet the supposition seems sufficiently supported that, under the climatic conditions of New York and on suitable soils, wheat does not cost per cental materially more to produce by intensive methods than barley or oats.

According to data in Table 17 (p. 363), the per-acre cost of winter wheat on investigated estates in Germany—with the charge for land equal for all grains—exceeded the cost of

¹⁶ This figure is calculated on the assumption of equal yields of spring oats and winter wheat, and of per-acre cost of wheat exceeding that of oats primarily through the dearer seed and the winterkilling, and partly because the winter-wheat straw has a slightly lower per-acre value than the oat straw. If considerably more manure and/or fertilizer is applied to wheat than to oats, wheat will outyield oats.

¹⁷ J. F. Harriott and L. M. Vaughan, *Cost Accounts on New York Farms* (already cited).

winter rye by about 15 per cent in prewar years and by about 10 per cent in postwar years. But all through those years, and in each of the three groups of estates, wheat outyielded rye. In most cases the excess was so large that the cost per cental of wheat was less than that of rye. If we allow for the frequently superior condition of the soil when the turn of winter wheat in the rotation comes, and the possibility that rye was grown on poorer soils on the same farms, the cost of production of rye would become somewhat less than that of wheat.

The cost of growing an acre of spring barley, according to the same data, was about equal to that of wheat; yields also were similar. The computed per-cental cost of producing spring barley on the German estates was somewhat higher than for wheat. Since both grains were probably grown on soil of about the same quality and in about the same places in rotations, the costs per cental of spring barley and winter wheat should be very close to one another. If it is accepted that spring barley costs 5 per cent less to produce per cental than winter wheat, it is in consideration of the fact that it is more convenient to grow a spring than a winter grain in regions of intensive agriculture.

According to the much less comprehensive data of Peters' earlier study (pp. 362-65), the cost was, in marks per quintal:¹⁸

Grain	Anhalt		Mecklenburg	
	1910-11 to 1913-14	1924-25 to 1926-27	1910-11 to 1913-14	1924-25 to 1926-27
Winter wheat	15.30	22.40	13.50	18.20
Spring wheat	16.80	24.50	.....	.....
Winter rye	15.40	24.30	12.80	20.60
Spring barley	15.50	22.10	13.70	19.30
Winter barley .....	.....	19.80	.....	15.00
Oats	17.60	19.80	11.70	17.70

Thus, again, the cost per quintal (or per cental) of winter rye was on the average higher than that of winter wheat, while

¹⁸ A. Peters, "Erzeugungskosten der wichtigsten Fruchtarten vor und nach dem Kriege" (already cited), p. 248.

the costs per cental of winter wheat and spring barley were approximately equal. The same data show that spring wheat costs more to produce than winter wheat, and this relationship seems correctly to reflect the lower yielding power of spring wheat as compared with winter wheat. The cost of producing winter barley was 10–15 per cent lower than that of winter wheat, and this finding fits well with the higher yielding power of winter barley.¹⁹

Oats, according to Peters, were cheaper to produce than rye but more expensive than winter barley. An adjustment for the poorer condition of the soil used for oats might have brought the cost per cental of oats down to that of winter barley. Differences in the quality of the soil occupied by each grain considered, the cost of producing oats per cental on the better lands of Germany may be 10–15 per cent less than that of winter wheat.

The estates investigated by Peters had above-average yields. On average farms with the same types of soils, the situation may have been slightly less discouraging for rye.²⁰ Yet the costs of producing rye on land that is fairly suitable to wheat could hardly have been greatly below the cost of wheat. On poor soils, however, the cost ratio becomes rapidly worse for wheat. In the experiments in eastern Prussia (Chart 23, p. 236), rye yielded 27 per cent more than wheat in the eight places of the next to the last group (group V on the chart). The ratio between the costs of producing rye and wheat per cental under these conditions was probably even more favorable for rye than the ratio of yields. In the eight places with the lowest yields rye outyielded wheat by 64 per cent, and the cost per cental was at least one-third lower for rye than for wheat. The cost ratio would have been still

¹⁹ The actual costs of winter barley are in some cases even lower because winter barley ripens ahead of the other winter grains, when pressure of farm work on some farms is less. But other farms are inconvenienced by the fact that winter barley has also to be sown very early.

²⁰ But this advantage has been lost in the meantime, because the utilization of commercial fertilizer has increased greatly in Germany since the years to which Peters' data apply.

more favorable to rye—almost indefinitely—unless the soils used for the tests had been heavily limed and fertilized. The cost situation on soils unadapted to wheat is approximately as favorable for oats as it is for rye, with qualifications introduced by the fact that rye is in the relatively best position on very light soils and oats on very heavy soils.

The meager data on yields of different small grains under irrigation presented in chapter xiii (pp. 331–33) suggest that wheat under irrigation yields better relative to the other small grains, in terms of percentages, than under dry-farming conditions. This change in yield may be attained without the relative per-acre cost being altered to the disadvantage of wheat. Hence the position of irrigated wheat is better on the basis of cost per cental also.

CORN

It seems proper to depart from the order of presentation previously followed and to begin the analysis of the relative cost per cental of corn from the region of the United States where corn is at its best, i.e., the heart of the Corn Belt.

In the heart of the Corn Belt.—In the rotations of the type corn-oats-winter wheat-hay, which are typical for the heart of the Corn Belt so far as winter wheat is included at all,²¹ the per-cental cost of producing corn is likely to be less than that of wheat by some 40 per cent, even with corn harvested at materially higher per-hour rates for labor.²²

The officially measured net costs per acre of corn on reporting farms in 1922–31 exceeded the corresponding figures by only 19 per cent in Iowa and by 10 per cent in Illinois (Table 17, p. 363). Moreover, if the reasoning on pages 379–80 is correct, these percentages should be sensibly reduced even for rotations most favorable to wheat. While the

²¹ These are rotations in which winter wheat cannot claim a remuneration for the service as a cover crop; rotations in which such claims are justified are of larger importance only in the southern and southeastern parts of the Corn Belt.

²² According to J. A. Hopkins, Jr., *The Crop System in Iowa County* (already cited), the ratio between the cost per cental of corn and wheat in Iowa County, Iowa, in 1926–28 was 57 to 100.

per-acre cost of corn on reporting farms did not greatly exceed that of wheat, reporting farms obtained yields of corn nearly twice as high as of wheat—93 per cent higher in Iowa and 96 per cent higher in Illinois. The ratios between yields of corn and wheat in the states of Iowa and Illinois as a whole in 1922-31, it is true, were not quite as favorable for corn as they were on the reporting farms; corn yields exceeded wheat yields by 84 and 89 per cent in Iowa and Illinois, respectively, as against 93 and 96 per cent on reporting farms. But an adjustment for this difference is hardly necessary, for in the two decades preceding 1922-31 the ratios between yields of corn and wheat in both states were more favorable to corn than they were in 1922-31.

The ratio between the officially computed cost of corn and oats in the heart of the Corn Belt can be used only for rotations in which oats have no claim for service as a cover crop. Moreover, the comparison can only be for the position as a principal crop, a situation without practical significance in the Corn Belt; the comparison in fact is good merely to give an idea on the extent to which such a position is out of line for oats.

The officially computed net per-acre cost of corn on reporting farms in 1922-31 was higher than that of oats by 36 per cent in Iowa and 34 per cent in Illinois. Corn, however, yielded 86 per cent (Iowa) and 89 per cent (Illinois) more than oats on the reporting farms.²⁸ Hence the cost of producing a cental of oats was respectively 36 and 39 per cent higher than the cost of a cental of corn. These percentages, moreover, need upward adjustment for various factors: probability of higher charges for land use on corn in official computations owing to its greater profitableness; insufficient charge for manure on oats; superiority of corn as a preceding crop. If oats are charged the same rates (except for rates of harvest labor) as corn and are not given credit for

²⁸ The ratios between yields in the states as wholes were approximately the same in 1922-31, and even more favorable to corn in 1927-36, when corn yielded 97 and 94 per cent more than oats.

certain services, the cost per cental of oats in the heart of the Corn Belt is some 40 per cent above the cost of a cental of corn. A cental of oats in fact would cost under those conditions substantially more to produce even on the basis of operating costs only, i.e., costs excluding the charge for land use. Yet in computations at uniform rates, a cental of oats is burdened with a charge for land use almost twice as high as the charge to a cental of corn.

The actual relationship between oats and corn in the heart of the Corn Belt is quite different, of course. A large part of the oats is entitled to a remuneration for service as a cover crop. Oats must also mostly be charged less for land use than corn because the long growing period of corn interferes with the growing of winter wheat (see p. 568). Last but not least, to be grown as a subsidiary crop, it is enough for oats to have a cost comparable not with the average cost of all corn but with the cost of that portion of it which in the common rotation with oats is grown at the highest cost (see tabulation on p. 565) and the accompanying text).

West of the heart of the Corn Belt.—There are rather strong indications that ratios between the per-cental costs of producing corn and small grains nearly as favorable to corn as those observed in the heart of the Corn Belt are found far outside of it. This seems to be true, in any case, in regions with good soil and a moisture supply which, though insufficient for the best yields of corn, still permits good corn harvests. The ratios between yields of corn and of small grains are not quite so favorable for corn in these regions as in the heart of the Corn Belt. But this disadvantage is largely offset by the fact that the ratios between costs per acre of corn and of small grains are more favorable for corn in regions supplied with less moisture. The improvement of the ratios between the per-acre costs of corn and wheat in favor of corn is particularly strongly marked, if from the Corn Belt we move into the region which is climatically unadapted for winter wheat, where corn competes with the less prolific spring wheat

and corn can also claim a remuneration for its beneficial effect on the yield of spring wheat following it in rotation.

In North Dakota, yields of corn on reporting farms exceeded yields of wheat by 65 per cent in 1922-31 (Table 15, p. 355).²⁴ But net per-acre costs were practically the same for both wheat and corn.²⁵ Thus the per-cental cost of wheat exceeded that of corn by 66 per cent, i.e., the same percentage which was accepted for the heart of the Corn Belt. The officially computed per-acre and per-cental costs would improve even more in favor of corn if this were given credit for its role as a preceding crop.

One naturally hesitates to assign to the official data on the ratio between costs of producing wheat and corn in North Dakota the same reliability as may be accorded, for example, to the ratios between costs of producing small grains in the Prairie Provinces. Aside from the fact that the "input" requirements and their seasonal distribution for corn and small grains vary more than for different small grains, the results are likely to be affected by the uneven geographical distribution of the corn crop over the state (the same is true of Kansas), and by inexactness of the data on corn yields.²⁶ Whether correct or incorrect, the favorable showing of the data on cost of corn production in North Dakota obviously can pertain only to the southeastern portion of the state, where the relatively high yields of corn reported to the Department of Agriculture must have been obtained. There are reasons to doubt the validity of the computations even for this area, but we let the official data stand and place the per-cental cost of wheat computed at uniform rates at 60-65 per cent above that of corn.

²⁴ Average yields in the state of North Dakota in the years to which the cost data pertain were approximately as favorable to corn (a 63 per cent excess of corn yield over wheat yield) as the yields obtained on the reporting farms. In 1927-36, it is true, the percentage was only 48 in favor of corn, but that decade is not representative.

²⁵ The relative decline in net per-acre cost of corn in North Dakota, as compared with the heart of the Corn Belt, was due to a high evaluation of the corn stover (see Table 15) rather than to lesser intensity of crop production.

²⁶ As to the latter, see F. F. Elliott and others, *Types of Farming in North Dakota* (U.S. Dept. Agr. Tech. Bull. 102, December 1928), p. 13.

Analysis of the officially computed figures for Kansas also gives results favorable for corn, though slightly less so than in North Dakota (Table 15). Yield ratios are much less favorable; yields of corn on reporting farms exceeded yields of wheat by only 46 per cent and the state average for corn in 1911-32 was higher by only 26 per cent. The ratio between the outlays per acre, on the other hand, was more favorable for corn in Kansas than in North Dakota. The cost per cental of wheat on the reporting farms, as officially computed, exceeded the cost of corn by 62 per cent. The officially computed cost ratios would be even more favorable for corn, if the loss of wheat from winterkilling were duly charged for. Owing to the less favorable yield ratio on all farms, however, it seems advisable to abstain from such an increase. The figure accepted by us is 60 per cent. This and the officially computed figure, of course, are valid only for the eastern portion of the state.

The ratios between costs of producing wheat and corn in Kansas as computed from official data are supported by findings for Nebraska. Computations of the Nebraska College of Agriculture (see Table 19, p. 373) show that on the average for 1927-33 and 1935, the cost to the tenant of producing a cental of wheat in four eastern counties exceeded the cost per cental of corn by 50 per cent. But the yield of corn, on the farms and in the years specified, exceeded the yield of wheat by only 33 per cent, whereas the normal yield ratio between these grains in eastern Nebraska would not be worse for corn than 150 to 100 (see the yield ratios in Chart 45, p. 305). The owner's share of the corn crop, moreover, is likely to represent a somewhat higher value than that of the wheat crop, while costs at uniform rates which are used in the comparisons call for equal charges.

In order to find, in regions with insufficient precipitation, a per-cental cost of production of wheat not exceeding that of corn by more than 25 per cent, it is necessary to move a rather long distance west or southwest from the western border of

the Corn Belt. Even in western Kansas, corn as a minor crop can frequently be grown at an outlay per cental of less than 80 per cent of the outlay on wheat.

West of the Corn Belt, the advantage of corn relative to barley in cost per cental declines considerably more sharply than it does relative to wheat. Oats may also gain somewhat over corn under the same conditions. But neither barley nor oats compete with corn in the Corn Belt. Their costs of production relative to that of corn are so vastly out of line, for permitting their production for their own sake rather than for their specific role in rotations, that a considerably lesser superiority of corn in per-cental cost of production computed at uniform rates may not prevent it from having strong competitive power, provided the specific role of oats and barley in rotation is less important. And this is what actually happens as one moves west from the heart of the Corn Belt. The diminishing advantage of growing corn in rotation and especially the lesser need for a cover crop materially weakens the competitive power of oats and barley for acreage as compared with their position in the Corn Belt proper. Barley and oats become dangerous to corn only where corn costs more to produce per cental. But the cost of producing corn may exceed that of barley and oats only in sections of the Great Plains most unadapted to corn owing to high elevation. Where climate is adapted to sorghum, however, the cost of producing this grain is materially less per cental than that of corn.

East and south of the heart of the Corn Belt.—The rate at which the per-cental cost ratio becomes less favorable to corn is also not rapid if, instead of moving from the heart of the Corn Belt westward, we move eastward, southeastward, or southward. The regions reached in this movement are partly too wet and partly too hot for corn. Intensification of crop production also is a factor in reducing the advantage of corn in cost of production per cental in portions of this region. For even where corn is still able to respond to manure and fertilizer considerably better than the other grains, it is mostly un-

able to respond better by anything approaching 65 per cent, the percentage needed to sustain the per-cental cost ratio found in the heart of the Corn Belt.

The yield ratios between corn and wheat as far east of the Corn Belt as Pennsylvania are as favorable to corn as in Iowa or Illinois. Even if the per-acre cost of corn in Pennsylvania is much farther above the cost of wheat than it is in Iowa and Illinois, a cental of wheat may still be more expensive to produce than a cental of corn by some 30 per cent or more. For New York the computations of the Cornell Experiment Station suggest even a materially higher cost per cental of corn than of wheat (\$3.23 per cental in 1914-31 as against \$2.65 per cental of wheat). But this finding is likely to make the situation unduly unfavorable for corn (see p. 384). In 1923-32, corn outyielded wheat by 69 per cent in New York state. The stover there represents a much greater value than the wheat straw (\$6.30 per acre of corn as against \$3.06 per acre of wheat on the average of 1927-30).²⁷ With a per-acre cost of wheat exceeding that of corn by 40 per cent (as assumed on p. 384), or even by 50 per cent, a cental of corn must be cheaper to produce than a cental of wheat. But the difference is hardly larger than 10-15 per cent in favor of corn, and there may be almost no difference in the per-cental cost of corn and oats.

The yield ratios between corn and wheat in several states south and southeast of Iowa and Illinois make a rather favorable showing for corn. In Missouri, corn outyielded wheat in 1923-32 by 73 per cent, in Kentucky by 61, in Tennessee by 74 per cent. In Macon County, North Carolina, the cost per cental of wheat on reporting farms in 1926 was 32 per cent higher than the cost of corn.²⁸ The data, though pertaining only to one county and one year, seem to be usable, since the ratio between the yields of the two grains on reporting farms

²⁷ According to J. F. Harriott and L. M. Vaughan, *op. cit.*, pp. 39, 44.

²⁸ R. E. L. Greene, *Cost of Producing Farm Products in North Carolina* (North Carolina Agr. Exp. Sta. Bull. 305, June 1936).

corresponds closely with the ratios between average yields in the state as a whole.

In Argentina.—Considering the rough nature of the data, one is surprised to find that computations of the costs of producing corn and wheat in the corn belt of Argentina, the second largest world producer of corn and the only really important corn exporter, give practically the same ratios as those reached for the heart of the North American Corn Belt.

In northern Buenos Aires, southern Santa Fé, and central Córdoba, the three regions with the largest corn production, the per-acre cost of corn exceeded that of wheat in 1933 (Table 21, p. 377) by 19, 30, and 36 per cent. But corn outyielded wheat in the same regions by 96, 88, and 142 per cent. Hence the cost per cental was higher for wheat than for corn by 65, 45, and 79 per cent. The higher charge for land use on corn in all these regions is undoubtedly due largely to the greater profitableness of corn rather than to better soil. With an equal charge for land use, a cental of wheat costs 72, 55, and 88 per cent more to produce than a cental of corn. Thus the cost of producing a cental of wheat in Argentine regions most adapted to corn is likely to exceed that of corn by approximately 65 to 70 per cent.

In the province of La Pampa, where the per-cental cost ratio between corn and wheat was least favorable to corn, a cental of wheat still cost 39 per cent more to produce than a cental of corn (according to official computations but with an equal charge for land use), and a charge in favor of corn for its beneficial effect on yield of wheat would have increased this percentage.

RECAPITULATION

It seems advisable to give a final glance at our computations of costs. The data are incomplete, in part meager. Some of the cost ratios have been based more on reasoning than on factual data, and some on reasoning only. The computed cost ratios, moreover, are not entirely comparable. Most of the

data have been so adjusted that the ratios can be regarded as ratios between costs at uniform rates. But the effect of the different proportions of acreages devoted to different grains on the per-hour rates for use of labor and/or capital could not always be eliminated. In some cases no attempt has been made to adjust the available data, and the cost ratios are given for what they are worth. Part of the findings are tabulated in Table 25.

TABLE 25.—RATIOS BETWEEN THE UNADJUSTED COSTS OF PRODUCTION PER CENTAL OF SPECIFIED GRAINS IN SPECIFIED REGIONS*

(Cost of wheat = 100)

Region	Rye	Barley	Oats	Corn
Prairie Provinces ...	83.5	69.0	77.0	....
North Dakota	83.5	71.5	81.5	....
California .....	....	75.0 ^a	....	....
Kansas	90	80	95.0-100.0	....
Central Germany				
(good soil)	90.0 ^b	95.0 ^c	85.0- 90.0 ^b	....
Heart of U.S. Corn				
Belt .....	....	....	85.0 ^d	60.0 ^e
Southeastern North				
Dakota .....	....	....	....	62.5
Eastern Kansas .....	....	....	....	65.0
Heart of Argentine				
corn belt .....	....	....	....	60.0 ^e

* The ratios are in general for crops produced at uniform rates, but the figure for corn in the U.S. Corn Belt is based on high labor rates at harvest time. Smaller differences in rates may be present in some other cases. Soils suitable for wheat and barley, the more exacting grains, were assumed. This assumption discriminates against the other grains, especially against rye and oats, which can be produced relatively more cheaply on poorer soils. Decimals in the table are not justified by the underlying data. In making estimates in the text we did not go beyond rounded figures. But the estimates in the text were frequently made for the excess of cost of wheat over that of other grains and lost their character of rounded figures when they were subsequently converted to the basis "cost of wheat = 100."

^a In sacks; ratios would be more favorable for the coarse grains if computed for bulk grain.

^b The percentages are probably valid only if rye and oats are produced in less desirable places of rotations. The cost ratios are likely to be less favorable for them if such less desirable places are not available.

^c Malting barley. Spring barley not intended for malting purposes may cost slightly less to produce. The ratio is materially more favorable for winter barley. The cost of winter barley might be assumed to approximate that of spring oats.

^d Ratio of costs in rotations with corn, for the south of the Corn Belt where winter wheat can more conveniently follow corn.

^e Valid for rotations yielding the most favorable ratios for wheat.

Certain grains, as we know, cannot be produced in certain climates at all, except in hothouses. Certain grains, furthermore, require specific soils. If the cost of producing a certain grain under conditions extremely unfavorable for it is compared with the cost of another grain for which the same conditions may be fair or even favorable, an exorbitant difference in cost results. Such ratios, however, are meaningless. If only those cost ratios are considered at which substantial quantities of grain are produced in a given locality, we shall be surprised to find that cost ratios do not vary much. The largest regional difference we can think of is that in cost of barley in terms of cost of wheat. Barley is produced at costs ranging all the way from 70 to approximately 100 per cent of those of wheat. The cost at which corn is produced varies from about 60 per cent of that of wheat to 85 or even a little more. But by far the predominant portion of rye and oats grown on good soils is produced at 80 to 90 per cent of the per-cental cost of wheat.

A cental of corn, the cheapest grain to produce under conditions most favorable to it, costs about 40 per cent less than a cental of wheat and about 25-30 per cent less than a cental of oats. These ratios are found in the heart of the North American Corn Belt and in Argentine regions most favorable for corn (northern Buenos Aires, southern Santa Fé, and central Córdoba), which supply the bulk of world corn exports. In moderately dry regions, such as those immediately west of the hearts of the corn belts in the United States and Argentina and in a large portion of the Danubian corn belt, the cost per cental of corn may be 30 to 40 per cent less than that of wheat. With a further decline in moisture, the cost ratios become unfavorable for corn rather more rapidly. In dry, very hot regions such as those of western Texas or Oklahoma, a cental of corn would cost almost as much to produce as a cental of winter wheat. So far as spring-sown small grains are concerned, corn may be more expensive to produce than barley only where warmth is greatly insufficient for it. A cental of sor-

ghum, however, can be produced in dry and very hot climates at much less than a cental of corn.

Intensive methods of production do not make the ratios between the costs per cental of corn and of small grains less favorable for corn only if they are applied moderately and under climatic conditions extremely favorable for corn such as those of the heart of the Corn Belt, perhaps not even there. In general, intensive methods cause an improvement of the cost ratios in favor of small grains. Still, regions in which corn can be produced per cental *substantially* cheaper than any small grain extend far to the east and southeast of the heart of the Corn Belt. But in North Atlantic states, as shown by data for New York, the per-cental cost of corn is hardly less than 85 per cent of the cost of wheat and may be as high as the cost of oats. Not only intensive methods but less favorable climatic conditions are of course responsible for this phenomenon.

On very poor soils wheat, the most expensive grain to produce, costs almost indefinitely more than any of the other grains except barley, if it is grown by extensive methods. On soils suitable for wheat, this grain is likely to be at the greatest disadvantage with reference to per-cental cost in drier climates with either too cold winters for winter wheat or mild enough winters for winter barley. On unirrigated lands of the spring-wheat regions of North America, and on unirrigated lands of California and North Africa, the cost per cental of barley is approximately 30 per cent less than the cost of a cental of wheat. The cost ratios seem to be somewhat less unfavorable for wheat in the Australian wheat belt, British India, and most of the Russian spring-wheat belt.

The competitive position of wheat relative to that of barley improves as we move into drier regions suitable for winter wheat but with too cold winters for winter barley. However, the improvement can be expected to be strong only where winterkilling is small, as in southern Russia. In Kansas, where losses of winter wheat from winterkilling are heavy, spring

barley may be cheaper to produce per cental than winter wheat by perhaps 20 per cent.

Ratios between per-cental costs of wheat and barley in moister climates make a considerably more favorable showing for wheat than in drier regions, especially if very intensive methods of crop production are used. Our computations for Germany show that, where winter barley can be grown, a cental of it is less costly to produce than a cental of winter wheat by about 15 per cent. In the much more important moister regions where winter wheat can be grown but the climate is unsuitable for winter barley and intensive methods are practiced, the advantage of barley over wheat in cost per cental may be as low as 5 per cent. Such is the condition in large parts of northeastern and north central Europe and in northeastern United States, so far as the latter are climatically adapted to winter wheat.

The ratios between the per-cental cost of producing wheat and oats on good soils display smaller regional variations than the ratios between the costs of wheat and barley. In regions unsuitable for winter wheat, a cental of oats may cost some 20 per cent less to produce than a cental of wheat (the hard-spring-wheat regions of the United States, Canada, and Russia). The cost ratios may be equally unfavorable or even more unfavorable for wheat in moist regions though winter wheat can be grown and winter oats cannot (Eire, Scotland, and similar regions). The advantage of oats over wheat in cost of production per cental is least, and may even be turned into an inferiority of oats, in regions with hot summers adapted to winter wheat but too cold for winter oats such as the hard-winter-wheat belt of the United States, and especially southernmost Russia where winterkilling is much less.

In moderate to cool regions well supplied with moisture, adapted to winter wheat but unadapted to winter oats, and practicing intensive methods, a cental of oats may cost 10-15 per cent less to produce than a cental of wheat. Such are northeastern and north central Europe, and the northeastern

United States so far as they are adapted to winter wheat and the moisture supply is not excessive for wheat.

The discussion of the ratios between the costs of producing wheat on the one hand, and barley and oats on the other, indicates also the relationship between the costs of producing barley and oats, the two grains which most frequently compete for the same place in rotations. Barley is tremendously more expensive to produce than oats on very acid soils. On soils suitable for barley and in a dry climate, on the other hand, barley costs less to produce than oats. Under extreme drought and heat, the difference in cost per cental may be as large as 20 per cent or more in favor of barley, but a difference of 10 to 15 per cent seems more typical. This superiority of barley is found in most drier regions used for growing small grains, such as the Great Plains of North America, the Pacific Northwest states, California, southern Russia, Mediterranean countries of Europe, Africa, and Asia, British India, and some minor regions, with the superiority of barley greater where barley and oats are grown as fall-sown crops. Most of the spring-wheat region of Russia in Europe and Asia, as well as the wheat belt of Australia, are now exceptions but may come into line after adapted varieties are introduced.

In moister regions, barley is seldom as cheap to produce as oats. Equal or lower per-cental costs are likely only where it is sufficiently warm for winter barley but too cold for oats. The more moisture, the greater is the superiority of oats in cost of production. In a very moist climate like that of Eire, the advantage of oats may be equivalent to 15 per cent or more. On very heavy soils, the superiority of oats may be of similar proportions even in a less moist climate.

Under climatic conditions unsuitable to corn, rye is the cheapest grain to produce on very light soils, while it is second to oats on poor heavy soils. The cost of rye on good soils is most favorable to rye relative to that of wheat in those regions where winter rye can be grown but winter wheat cannot, and methods of crop production are extensive. A cental

of rye may cost some 20 per cent less than a cental of wheat in every hard-spring-wheat region of the world. Where winter wheat can be grown along with winter rye, and either the climate is hot or intensive methods of crop production are used, a cental of rye on good soils may cost almost or approximately as much as a cental of wheat, provided there is no substantial difference between the two grains in the amount of winter-killing. Such approximately equal costs of wheat and rye are found on highly cultivated lands of northwestern and north central Europe, but also on good lands of southern Russia as well as all over the southern United States. But in Kansas rye may be cheaper to produce by perhaps 10 per cent owing to heavy winterkilling of wheat.

To what has been said above, one comment should be added. Where farming is conducted partly or wholly at the expense of nutrients and organic matter contained in the soil, farmers are in the habit of largely disregarding the fact that the amounts of nutrients and organic matter lost by the soil, owing to its use for crop production, differ according to the crop grown. Hence nutrients and organic matter are not regarded as elements of cost, or so treated in cost computations, and have no effect on the competition for the land. The writer therefore did not see fit to adjust for that difference the costs discussed. But with the spread of knowledge, farmers are likely to become aware of it; and this will make the difference a practical one also as a cost factor, a factor determining the competitive power of the different crops for the land. Then the fact will become significant that corn is much more soil-depleting than small-grain crops (p. 233). The particularly favorable showing which corn makes in cost of production relative to small grains in regions of extensive agriculture is due partly to the fact that it is not charged, or not charged fully, for the greater depletion of the soil. This part of the superiority of corn is likely to disappear as time goes on, although with reference to soils of high natural fertility the time may well be remote.

PART IV

PRICE RELATIONSHIPS VERSUS COST RELATIONSHIPS

CHAPTER XVII

THE FIVE GRAINS

The presentation has reached its final stage. The differences in the ability of each grain to satisfy various consumers' needs have been analyzed (chapter ii). It has been shown how consumers' preferences are reflected in prices (chapters iii and iv). A further step was to analyze the effect of differences in the quality of individual grains, marketing costs, and protectionist measures on the inter-grain price ratios in the same localities (chapters v-vii). Furthermore, it has been determined what are the differences in the requirements of the various grains as to soil, temperatures, and moisture, and in their responses to cultural practices (Part II). Finally, the relationships of one grain to the others in the cost of production have been taken up (chapters xv and xvi).

Part IV is intended primarily to integrate the findings of Part I with those of Parts II and III, but has been extended so as to serve also as a summary. A comparison between the rankings according to prices that consumers pay or would be prepared to pay if necessary, and the rankings according to the cost of production, helps greatly toward disclosing the competitive position of each grain under different conditions. In general it explains satisfactorily why in a given territory a certain grain is grown solely or mainly while others are not produced at all or are produced only in small quantities.¹ By and large, production and prices are well in balance. But, aside from some exceptions, this balance is repeatedly disturbed by changes in consumers' evaluations, on the one hand, and by the development of new varieties and changes in production techniques and prices of means of production on the other hand. To disclose the points where production and

¹ The relation between the price and cost ratios of different grains evidently cannot disclose the relation of grains to other crops. They may point to some grain as the most profitable; yet some other crop may be still more profitable, and the grain in question be produced, if at all, only as a secondary crop.

prices are not in balance as well as the probable changes in price and cost ratios in the future is the most intriguing portion of our task, but unfortunately it is very difficult to make much headway in this direction.

GENERAL ASPECTS

The approximate and of course very general rankings of different grains according to prices (paid or to be paid if necessary) and according to the cost of production as found in the preceding analysis are, from the highest prices and costs to the lowest:

According to prices		According to costs	
1. } Wheat and malting barley		1. Wheat	
2. } Rye as food		2. Malting barley	
		3. Rye	
United States	Other countries		
4. Corn	4. } { Oats for horses and	4. } Barley and oats	
5. } { Oats, feed	5. } { barley for hogs	5. } {	
6. } { barley, and	6. } { Oats and feed	6. Corn	
7. } { feed rye	7. } { barley for		
	8. } { purposes other than		
	9. } { 4 and 5, corn, and		
	} { feed rye		

The two rankings show significant similarities. Wheat occupies the top place in both. Oats and feed barley in the price ranking outside of the United States are found in the fourth and fifth places, for the very important uses as horse and hog feed, respectively, and these grains occupy the same places in the cost-of-production ranking. Rye in the cost ranking is in the same place as in the ranking according to its evaluation as food.

The major differences between the two rankings are that rye as feed has the lowest or nearly the lowest value to the consumer, while it ranks third in cost of production. A further difference is that corn even in the scale for countries other than the United States, less favorable for it, ranks higher

according to price than according to cost. In the United States corn according to price ranks immediately below wheat and malting barley (or below wheat, malting barley, and rye, so far as the latter is evaluated as a food), while it is lowest in the ranking according to cost.

These discrepancies between the rankings according to prices and according to costs, small as they appear, would considerably affect the distribution of the world production between different grains, bring about material differences in the position of individual grains in the rotation (principal vs. subsidiary grain crops), and cause substantial variations in the value of different land (higher value of land particularly adapted to most profitable grains). But the effect of the discrepancies between the two rankings is strengthened by two facts. First, even where the places of certain grains are the same in both rankings, the spreads between prices are not always of the same magnitude as the spreads between costs; the cost of producing corn is so much lower than the costs of producing oats and barley that the production of corn remains at a large advantage even where corn is priced sensibly lower than the other feed grains. Second, consumers are prepared to pay for very large quantities of wheat so much more than for feed grains that the handicap of the higher cost is easily overcome. The difference between the usual evaluation of rye and wheat for food also definitely tends to be larger than the difference between the costs of these grains on better lands.

The two dominating grains.—Thus the connection between the positions of different grains according to price and according to cost is broken from both ends. Consumers are prepared to pay for wheat (and malting barley) considerably more in comparison with their relative cost; and it costs relatively much less to produce corn than this grain is worth to the consumer. The different approaches in the case of wheat and corn may seem simply a play upon words, for in both cases the consumer is prepared to pay relatively more than the rela-

tive cost to produce the goods. Yet the difference between the position of the two grains seems significant. Wheat is an expensive grain to produce, and it derives its strength from its position with consumers, who consider it irreplaceable by other grains. Corn, on the other hand, does not command a place with consumers comparable with that of wheat; it can easily be replaced by other grains. Nevertheless corn is much more used for feed than any other grain, because corn can be produced so much more cheaply than its potential substitutes.

The favorable position of wheat with consumers and the similar position of corn with producers explain the superiority of wheat and corn in world production. Either of these grains is grown (or both simultaneously) in the greatest possible quantities on land which in soil quality and climate is suitable for their production. Under climatic conditions favorable to corn, land used for it yields an extra rent which is the outcome of the low cost of production of corn relative to its evaluation by consumers. The same is true of good wheat soil in drier regions. Last but not least, the high evaluation of wheat by consumers relative to its cost of production and the low cost of corn relative to its evaluation as a consumer's good account for the fact that these two grains dominate the international grain trade.

Wheat occupies a dominant position on good soils only in drier regions because, with a sufficient supply of moisture, the good soils adapted to wheat yield high returns not of wheat alone but of many crops, and several of these crops are as profitable to produce as wheat or are even more profitable. Provided temperature conditions are suitable, corn is one of the crops which prove more profitable than wheat on good soil supplied with sufficient precipitation. Since wheat has to cede its place, although such lands are well adapted to wheat, corn must be considered superior to wheat in competitive power. This obviously is not an inherent property of corn, and not many decades ago the situation was the reverse. The change was brought about by improvement of corn prices relative to

wheat prices. But with present price ratios, world production of corn would have far exceeded that of wheat (now world production of corn is about 20 per cent less; see Chart 1, p. 1) unless, outside the United States, corn growing on a large scale were not limited by its rigid requirements as to climate to a few relatively small areas (see Chart 48, p. 446, world acreage in corn). Of course, the price of the prolific corn would be materially less relative to those of the other grains, if it were not for the strict climatic limitations to its production.

The three other grains.—The fact that substantial amounts of grains other than corn, wheat, and malting barley are produced (Chart 1)² is to only a relatively small extent traceable to the role of those grains as consumers' goods. Experience in most of the United States—a country with incomes of broad masses the highest in the world—shows clearly that a high class of consumers is well satisfied with wheat as practically the sole food cereal and with corn as practically the sole feed grain. The demand for rye for bread and liquor amounts to a few million bushels per year each. The demand for oats and barley for food is approximately of the same magnitude. Even the demand for barley as material for beer makes up only a few per cent of the demand for wheat. No demand for feed barley or feed rye exists which could not be satisfied by corn at the same price per cental. Only oat prices are occasionally much higher than those of corn, but the demand for them too would shrink considerably if oats were continuously much more expensive than corn. In certain countries of western Europe consumers would probably continue to use feed barley for a long time at a price materially higher than that of corn, but again relatively small quantities are involved.

Consumers' preferences, in fact, are more important in the competition among the three grains now considered than in

² The figure on barley in the chart covers barley used for all purposes. The quantity of barley used for beer is equivalent to slightly more than 10 per cent of the total.

their competition with wheat and corn. On soils adapted to no other grains save rye and oats, for example, the proportion of rye and oats produced depends largely on whether rye bread is consumed locally. In the competition between oats and barley, the kind of livestock to be fed on farms exerts a relatively strong influence on the selection of grains grown. Considerable amounts of oats are grown in drier regions on farms because, and so long as, horses are kept on them. The disappearance of horses frequently brings about a shift to barley.

One has to look to the position of rye, oats, and barley in the production process in order to find the principal reasons for their relatively large production. A considerable proportion of land used for crops is unadapted to wheat, owing to the poor quality of the soil, and also fails to satisfy the specific climatic requirements of corn. Oats and rye, the two crops inexacting with regard to soil, are the principal beneficiaries. Of importance also are the relatively high yields of oats in moist and cool climates, and of barley in some regions with dry and relatively hot climates.

The considerable advantage of growing crops in rotation is another factor responsible for the production of large quantities of rye, barley, and especially of oats. Corn and wheat, it is true, alone or together with some nongrain crops, combine into good rotations, in which corn is the high-yielding and wheat the highly priced grain member. Wherever practicable, the combination of corn—winter wheat proves the most invincible of all combinations of grains, one of them being the leading and the other the subsidiary grain crop, or both being approximately of equal rank. But this combination has considerable natural limitations. There is plenty of crop land which, while suitable for wheat, is unadapted for corn, or vice versa, or, being suitable for both grains, is climatically unadapted for the sequence of corn—winter wheat—the most effective combination of these two grains. In all such conditions, there is ample room for oats as a grain crop subsidiary to corn or wheat. Oats, moreover, are widely grown

in rotations with nongrain crops. To a lesser extent, barley and rye too profit from such situations.

REGIONAL ASPECTS

The analysis in the preceding chapters not only yields a general idea as to the competitive position of different grains in the world as a whole, as presented in the foregoing section, but indicates also endless regional divergences in their competitive power. Indeed, the short summary of the findings in the few preceding pages could not be made without repeated mention of regional peculiarities. The most significant line of regional differences is that dividing drier from moister regions. With regard to the moister regions, a distinction should be made between regions practicing extensive methods of crop production and those practicing intensive methods. The drier regions have no choice but to stick to extensive methods.⁹

The regional divergences in competitive power are brought about by differences in both price and cost relationships. Differences in price relationships to some extent reflect differences in cost ratios and vice versa. Other factors responsible for the regional variations in price ratios are:

1. Consumers' preferences vary in different regions; for example, corn as feed is evaluated more highly in America than in some important European and especially Asiatic countries (see chapters ii and iii).

2. Marketing costs are approximately equal per cental for all grains. Moreover, the cost of marketing wheat, the most expensive grain, is sometimes less than that of barley and—more frequently and more markedly—less than that of oats. Hence marketing costs tend to make the price ratios more favorable for wheat in regions whence the grain is shipped (usually drier regions) than in those to which it is shipped (commonly moister regions).

⁹ Intensive methods in general denote large input of any kind for higher and safer yields. Specifically one speaks of labor-intensity, capital-intensity, and so forth.

3. The quality of wheat produced in moister and especially in *moist* areas is substantially inferior to that of wheat produced in drier conditions, while the opposite is true of barley and oats. The quality of corn does not show material regional variations, except where the amount of warmth or the length of the growing season are insufficient for ripening. Only the quality of rye displays the same tendency as does that of wheat of deteriorating with increase in the amount of moisture, but the effect of this deterioration on rye prices is less than in the case of wheat (pp. 122-32).

4. Import duties are arbitrary and do not perforce influence the price ratios in a consistent direction. Wheat, or in some countries rye, is the grain which most frequently enjoys the relatively greatest protection (pp. 177-85).

Regional differences in the ratios between the costs of production of different grains are brought about by differences in the requirements of the grains as to soil and climate and their response to cultural practices, as well as by the general level of grain prices relative to the prices of factors of production, especially of prices of commercial fertilizer, which determine the degree of intensity advisable for each crop. The most pertinent of these factors should be reviewed here.

1. Wheat and barley are exacting in their soil requirements; the types of soil which predominate in moister areas are mostly unsuitable for them, especially under extensive methods of crop production.

2. Corn is particularly exacting in its temperature requirements.

3. Winter rye can be grown in certain important drier regions although fall-sown wheat cannot survive the winter. Wheat has to compete here with winter rye, spring barley, and spring oats in its less prolific form as a spring-sown crop. In moister regions, on the other hand, much land is climatically adapted to winter wheat but unadapted to winter barley and winter oats.

4. Barley sown in the same season as wheat withstands heat better than wheat.

5. In terms of grain harvested, corn utilizes large supplies of moisture better than any other grain, oats not excepted.

6. Oats withstand much moisture better than any other grain.

7. The expensive wheat in general is substantially more able to repay cultural practices than the other grains, and only in moister climates can cultural practices be applied abundantly.

Let us now see how the different factors influencing the price and cost ratios combine to affect each grain in important regions, and what is the relationship between the cost and price ratios in each of these.

Wheat.—Two factors mentioned as affecting regional variations in price ratios—marketing costs and variations in the quality of grains—tend to make the price ratios most favorable for wheat in drier surplus regions, while they are least favorable for wheat in moister deficit areas, provided the price ratios are not changed by government interference. But owing to its lesser ability to thrive on scarce moisture as compared to barley, wheat even on adapted soils makes one of the worst showings in relative cost of production in those extended drier regions where winter wheat cannot be grown owing to climatic conditions, or where it is possible to grow winter barley also. The relative cost of producing wheat on adapted soils may be even more unfavorable to it only in regions climatically well adapted to corn, and perhaps also in moist climates particularly favoring oats. On the other hand, provided the soil is not an obstacle, the ratios of the cost of production of wheat to those of the other small grains are least unfavorable for wheat in those moderately moist areas which are adapted to winter wheat but unadapted to winter barley and practice intensive methods of crop production. The relatively limited areas with soil suitable for wheat located in those moister regions in which extensive methods are in vogue, together with drier regions the climate of which is mild enough for winter wheat but too severe for winter barley, occupy intermediate positions.

Thus the main course of regional changes in price and cost ratios between wheat and the coarse grains here studied is in the same direction; coarse grains come closer to wheat in both price and cost. The competitive strength of wheat in its struggle for land shows therefore less regional differences than might be expected from the fact that there are such large differences in both price and cost ratios. This occurs partly because one of the main causes of the differences in the price and cost ratios is the same, and its effect on the competition of wheat is compensating rather than cumulative. The relatively high and about equal marketing costs from surplus to deficit areas bring it about that the spreads between prices of different grains, expressed in percentages, are much less in deficit than in surplus countries. *Ceteris paribus*, this greatly lessens the competitive power of wheat, the main bread-grain, against coarse grains in production in the deficit areas. But the substantial increase of the level of grain prices in deficit countries caused by the same marketing costs makes it profitable for those countries to indulge in intensive methods of crop production, especially to use large amounts of commercial fertilizer, and this again favors wheat.

Since the cost and price ratios of wheat to those of the other grains tend to change from drier surplus regions to moister deficit regions in the same direction, the effect of these changes on the competitive power of wheat depends on the relative strength of the changes in those ratios. There is in fact sufficient difference between the strength of these changes to bring about paramount divergences in competitive power.

The fact that the cost ratios are very unfavorable to wheat in many drier regions is in general greatly overcompensated by the fact that the price ratios are very favorable to it. In such regions the cost of producing barley, the strongest competitor of wheat, is less than that of wheat at best by 30 per cent except in very restricted localities. Where wheat enjoys the advantage of being able to survive the winter while barley can be sown only in the spring, the advantage of barley in the

cost of production is considerably less, and under great summer heat winter wheat may not cost materially more to produce than spring barley.⁴ But most drier regions being located at long distances from deficit regions, and owing to the divergent effect of scarce precipitation on the quality of the grains, the prices of barley and the other coarse grains must be some 30 to 40 per cent less than the wheat price in these regions, if coarse grains are to be on an export or shipping basis to the same extent as wheat.

This relation between price and cost ratios affords wheat the possibility of almost fully dominating on good soils in those drier regions where it can be grown as a winter crop while barley can be grown only as a spring crop. But the price advantage proves sufficient for such almost complete domination, at least for some time after the land has been broken, even where spring wheat competes with spring barley (and spring oats) and where, save under some more or less exceptional conditions, fall-sown wheat competes with fall-sown barley. In spite of the fact that the relative cost of producing wheat is very unfavorable in several important drier regions, almost three-quarters of the world wheat acreage (ex-China) is grown in drier regions without irrigation.

While wheat in distant drier *surplus* areas tends to cost 45 to 65 per cent more than feed grain, the usual price margin in moister importing countries practicing intensive methods of crop production does not exceed 10-20 per cent in its favor, provided government interference does not change the "natural" price-relationship. As compared with this large improvement in price ratios in favor of feed grains, the improvement in cost ratios in favor of wheat is only moderate. On soils adapted to wheat, the cost ratios between wheat and the other small grains tend merely to be close to the ratios between their market prices. Thus there is no reason for the domination of wheat in production. Moreover, since wheat

⁴ Sorghum is the only grain which can be produced much more cheaply than wheat under these conditions.

is mostly marketed, while feed grains are used on the farm, the latter may have the stronger claim on the land. On soils only moderately suitable to wheat, the ratio between market prices may even be less favorable to wheat than the ratio between the costs of production. Last but not least, a large proportion of soils in moister regions is unsuitable for wheat. The role of wheat production in moister regions would be still less if it were not more favored by government protection than the other grains.

Corn.—Corn, a crop somewhat reluctant to thrive where moisture saturation of the soil is at the minimum permitting growth of plants, has little competitive strength in regions with borderline conditions as to moisture, especially where the temperatures are high enough for sorghum. With increase in moisture, a place is opened for corn as a crop subsidiary to wheat, because corn sensibly outyields the other feed grains (except sorghum in some regions) and exerts a favorable effect on the yields of wheat following it in rotation. On soils unsuitable for wheat, as in most of Nebraska for example, corn even becomes the predominant crop in spite of the moderate moisture supply. Further increases in precipitation make the cost ratios increasingly favorable for corn. In temperature conditions like those of Iowa, corn attains its greatest competitive power at an annual precipitation of 30 to 40 inches. There it is more profitable than wheat even on soils best adapted to the latter. If wheat proves unsuitable as a subsidiary crop under such conditions, it is banished entirely.

Moderate intensification of methods of crop production does not necessarily change sensibly the cost ratios of corn and other grains in temperature conditions very favorable to corn. But the cost ratios are much less favorable to corn where large amounts of fertilizer of any kind are applied. Where, owing to cheapness of labor, capital intensity is combined with labor intensity, corn, a row-crop, also meets more competition than small grains from still more intensive row-crops such as

beets and potatoes. Yet, so far as temperatures remain satisfactory for corn, its higher yielding power generally suffices to preserve for it the place of the leading crop or the leading grain crop in moister intensively cultivated regions, especially on poorer soils unadapted to wheat. Regions of very intensive use of capital and labor may be exceptions, it is true.

Barley.—As we know, the fact that barley tends to have the greatest advantage in the cost of production over wheat in a drier climate mostly fails to deprive wheat of the predominant position in such regions. As a crop secondary to wheat in drier regions, barley is helped by the fact that it usually costs less to produce than oats; but spring barley encounters the competition of corn for this place in drier regions sufficiently warm for corn. Barley loses any chance in dry regions with summer rains which are sufficiently warm for sorghum.

In none of the drier regions where either winter wheat can be grown while the climate is too severe for winter barley, or where both grains can be grown merely as spring grains, is barley able to attain a better position than that of a crop subsidiary to wheat, and mostly of an unimportant subsidiary crop at that; some time, moreover, may elapse after the land has been broken before any barley becomes established. Barley fetches 60–70 per cent of the price of wheat in many such regions, but it costs 70–75 per cent as much to be produced in very large quantities even in the hard-spring-wheat regions of the United States and Canada and in the southwest of the Russian spring-wheat belt which have the most favorable cost ratio for barley among those regions. The cost of producing small quantities of barley as a subsidiary crop makes a showing more comparable with that of wheat, it is true, and there are many lands on which—owing to northern location, large amounts of weeds, and so on—the same is true of larger quantities.

Where cost ratios between barley and wheat are less favorable for barley than in the regions mentioned, barley frequently fails to get a footing at all, as for example in most of

the American hard-winter-wheat and the Russian spring-wheat regions.

Barley is more successful in its competition with wheat in drier regions warm enough for winter barley, although the relative costs of producing it in large quantities are in general not more favorable for barley than in some regions growing spring barley and spring wheat, and, moreover, no advantage mostly can be gained from growing barley as a subsidiary crop. Extreme poverty and extreme wealth of the population are among the pertinent factors helping barley to become an important crop, even the predominant one, in some of such regions. The natives of French North Africa and many Asiatic countries cannot afford to eat the wheat they are able to produce on their land and are compelled to produce for their food the grain which yields best, and this is barley. In California, on the other hand, they can afford to discriminate against the type of wheat produced locally, while the state is on an import basis as to feed grains (see the price ratios in California in Chart 4, p. 12). But in the dry farming of Spain, British India, and some other countries, barley is far less important than wheat, while in Australia fall-sown barley thus far has failed to get any footing whatsoever.

In the shift from drier to moister areas, the relative cost of producing barley rises more than that of any other grain. In the latter, barley seems to be on an equal basis with oats or to possess some advantage over them in cost of production merely where barley can be sown in the fall while oats can be grown as a spring grain only. But the winter-hardiness of barley is not much larger than that of oats, and, except in the Pacific states and some regions in western Europe, moister regions adapted to winter barley are also sufficiently warm for the higher yielding corn. Spring barley, however—with a cost of production in moister regions commonly higher than that of oats—is able to obtain there an important place in production, mainly if destined for use materially higher than feed. At least a chance of obtaining a price substantially in excess of

that of feed grain must be present to induce the producer to devote a large acreage to spring barley. Hence some 70 per cent of the world acreage in barley (ex-China) is in drier regions—almost as large a proportion as that of wheat.

Oats.—Oats usually cost more to produce per cental in drier regions than barley. Hence they have no place in production on good soils of those regions for shipment out of the region. Needs of the farmers themselves, coupled with the protection of marketing costs, are the principal reasons why some oats, and sometimes rather substantial quantities, are produced there. Soils less adapted to either wheat or barley constitute another but a minor reason.

In moister and especially in really moist areas with temperatures too low for corn, oats are the cheapest grain to produce, except for the moderately moist regions where winter barley but not winter oats can be grown and the cost of producing oats and barley on good soils is approximately the same. The suitability of oats to almost every soil and to every place in rotation, and their high value as a feed supplementary to the types of feeds produced and used in large quantities in moister regions (hay, pasture, and roots), give them a strong footing.⁵ Seldom, it is true, are oats a principal crop, as wheat and corn are in their respective regions. Oats commonly represent a subsidiary crop, and the costs of production computed in the usual way invariably show losses if compared with prices. Moreover, as is true of the other coarse grains, relatively larger amounts of oats than of wheat are produced only because the producers are prepared to accept extremely low incomes (see pp. 435-37).

Intensive technique makes it less inevitable to use the poor soils for oats. Moreover, except probably in very moist regions, the resort to intensive methods of crop production slightly detracts from the competitive power of oats, owing to their somewhat lower response to cultural practices.

⁵ Where feed grain is grown supplementary to potatoes produced as feed and mostly used for hogs, barley or rye may be preferred to oats as a supplementary feed.

Rye.—Even though in many drier regions wheat can be grown only as a spring crop, while only restricted localities are too cold for winter rye, rye has material competitive power in those areas only (a) on soils unadapted to wheat and barley, (b) under extremely primitive methods of crop production which handicap the more exacting wheat, and (c) if rye can fetch a relatively good price as a food grain.

In moister regions rye, in competition with wheat, has mostly to face winter rather than primarily spring wheat. It is handicapped further by the fact that it is inferior to all other grains in the response to cultural practices. The only advantage of rye on better soils in moister climates is its adaptability to less desirable places in rotations. But oats frequently prove preferable for this purpose. The very poor soil prevalent in moister regions with cold climates is the principal strength of rye; bread is needed and rye is the only bread grain that the soil will produce safely. Where it is essential to use such poor soils for crop production, considerable quantities of rye are grown even for use as feed.

No rye is grown where temperatures are adapted to corn either in drier or moister regions.

In brief.—Thus we have the following broad course of changes in competitive power of different grains as affected by climate, in temperate zones of the Occidental world.

In *dry regions*, wheat is the leading crop; barley is the strongest competitor especially on poorer soils, except for very hot regions with summer rains where sorghum is wheat's strongest competitor, also especially on poorer soils.

In *moderately dry regions, on the better soils*, wheat is the leading crop; corn is the strongest competitor where temperatures and seasonality of precipitation are suitable; otherwise the choice goes to barley, in cooler climates also to oats grown for horses kept in the locality, or to rye as a food. *On the poorer soils* of these moderately dry regions, the leading crop is corn where climate permits; otherwise oats and rye.

In moderately moist regions, cultivated extensively to mod-

erately intensively, corn is the leading crop where temperatures and seasonality of precipitation are suitable; wheat is an important subsidiary crop provided the soil is adapted to it and winter wheat can follow corn in rotation, and if not, oats are important as a subsidiary crop. If temperatures are too low for corn, wheat is the leading grain crop on better soils, otherwise rye and/or oats; oats on better soils also as a rotation crop; and/or barley either for beer or as a winter crop.

In *moderately moist, intensively cultivated regions*, the modifications are that corn is much weaker and wheat stronger.

In *moist regions*, corn dominates if the climate is hot, rye and especially oats if it is cool; and some wheat is grown on better, intensively cultivated soils.

QUALITY OF LAND⁶

The quality of the land as a factor affecting competition among the grains deserves some further comment, supplementary to both the regional and the general aspects. Whether a certain good is produced at a particular place is determined much less by the advantage of producing it at this place as compared with producing it at some other place, than by the relative advantage of producing different goods at the same places. Interregional competition is imperfect. This is especially evident in agriculture, owing to the conservative character of the farm population in general and especially to the family character of the farm business. People work the land on which they settled. If they happen to have settled on good land they tend to be better off, and vice versa. There are of course pertinent offsetting factors: good lands tend to be populated more densely; poor soils are to a much larger extent located in regions better adapted to the development of industries; the people on poor lands on the average are more energetic. Yet the quality of the land as a factor determining

⁶ For a broader discussion, see Ellsworth Huntington, "The Handicap of Poor Land," *Economic Geography*, July 1926, II, 335-57.

This small section drew the most criticism in the Food Research Institute.

the whole mode of life was of paramount importance in the past and remains so to a considerable extent.⁷

The quality of the land as a factor affecting farmers' incomes is strong not only between countries but within countries. It suffices to recall the plight of farmers in the southern Appalachian and other mountainous regions of the eastern United States.⁸ Farmers on poor land tend to be poorer even in the same locality and in such exceptionally favorable surroundings for the change of occupations as those found in the state of New York.⁹

We cannot discuss in any detail the vast problem of the effect of the quality of land on the people living on it, but we also cannot pass it by unmentioned because competition among grains is sensibly affected by this factor.

Every grain is grown to some extent under conditions under which it would not be grown if migration were a more potent leveling factor. Some wheat is grown in regions with so little moisture that incomes comparable with those obtained on better watered lands cannot be secured. Corn is the grain which lends itself most easily to production by man power only. It is therefore rather extensively grown on small patches in the mountains where animal power cannot be used. To some extent, corn is also grown on poorer lands of other

⁷ J. R. Smith, *Industrial and Commercial Geography* (New York, 1913), p. 64, writes: "Where the land is poor and weather cold, the people are also usually poor." See also Isaiah Bowman, "Our Expanding and Contracting 'Desert,'" *Geographical Review*, January 1935, XXV, 51.

⁸ See, for example, *Economic and Social Problems and Conditions of the Southern Appalachians* (U.S. Dept. Agr. Misc. Pub. 205, January 1935).

⁹ See the very illuminating investigation by A. B. Lewis, *An Economic Study of Land Utilization in Tompkins County, New York* (Cornell Agr. Exp. Sta. Bull. 590, April 1934). It shows that no labor income is earned on farms with the poorest land. The larger the farm, the poorer is the farmer on such land, since he has less time for outside work. Since there is no real net income on poor land, there is no room for an owner-tenant relationship, such farms being operated by owners exclusively. The price of land largely fails to offset differences in its quality. If a reasonable charge for labor is included in the accounts, the poorest farms had a negative value amounting to not less than \$13,000. The findings for Tompkins County are corroborated by studies made in several other counties of the same state. See T. E. LaMont, *Land Utilization and Classification in New York and Its Relation to Roads, Electricity, and Reforestation* (Cornell Extension Bull. 372, March 1937), p. 23.

type. The three "nearest" that barley boasts, i.e., production nearest to the sky, nearest to the poles, and nearest to the desert, all designate conditions under which no crops would be grown unless the people living there were hopelessly detached from the rest of the world. Yet oats and especially rye are likely to be the largest gainers from insufficient migration. A very substantial portion of world production of rye is grown on land which is worked only because migration is insufficient even within countries.

Moreover, if production of wheat on the most unadapted lands were to cease, the missing quantities would be produced somewhere else. The same is likely to be true of part of the corn so produced. Both wheat and corn would also gain from the discontinuance of the production of barley, oats, and rye on land not yielding sufficient returns now. In the final analysis, barley, oats, and rye are likely to be the only three among the grains here studied the production of which is expanded by insufficient migration.

HISTORICAL ASPECT

A long view.—Lacking sufficient statistical data, little can be said, without extended study, about the actual development of each grain in the longer past, except that corn and wheat greatly gained, and rye—millet even more—greatly lost in importance in the world over the last thousand years. But some general considerations seem in place.

Numerous examples of rapid spreading of some of the grains from their original or secondary homes¹⁰ may easily be found. Such, for example, was the spread of wheat pro-

¹⁰ According to recent extended investigations, the results of which were presented to the Second International Congress of Soil Science by N. I. Vavilov ("The World Centers of the Origin of Agriculture and the Soil Map of the World," *Second International Congress of Soil Science*, Moscow, 1932, IV, 81-85), southwestern Asia, including northwestern India, is the place of origin of common wheat (*triticum vulgare*) and rye; southeastern Asia, chiefly eastern and central China, of millets; northeastern India, of rice; Abyssinia, of durum wheat and barley; and Central America and northern South America, of corn. More specifically the origin of corn is placed in the Andean region of northwestern South America. P. C. Mangelsdorf and R. G. Reeves, *The Origin of Indian Corn and Its Relatives* (Texas Agr. Exp. Sta. Bull. 574, May 1939), pp. 62-70.

duction over the almost endless plains of southern European Russia, Siberia, North and South America, and Australia. But in general the spreading of grains over the earth is, and especially was, a very slow process. Five hundred years seems almost endless in comparison with the present-day rate of technical developments. Yet effects of the fact that before Columbus the New and the Old Worlds did not communicate regularly are easily traceable in the distribution of both consumption and production of at least two important grains (corn and millets). Moreover, the ideas on the desirable types of cereal food are almost as divergent in the Orient and the Occident now as they were a thousand years ago.

The reasons for the failure of the several grains to attain the places which they deserve according to their ability to satisfy consumers' needs, and to their adaptation to soil and climate and cultural methods of crop production of each locality, were on the side of both consumption and production. Consumption was mostly the minor factor. On the whole, men consume—and even more used to consume—what they can produce or otherwise get with the least effort. But once established, food habits persist, especially if consumption of some food, as, for example, rice in the Orient, becomes a sign of distinction. So far as concerns the controversy between the Orient and Occident as to whether boiled rice or baked bread is better as the principal cereal food, there is at least no objective superiority of one food over the other. But the preference of the natives in India and the Union of South Africa for sorghum against corn (see p. 38) seems wholly unwarranted, because there is hardly a food preparation which is not superior if corn rather than sorghum is used as the material. Even in the United States, where farmers probably get more advice than farmers of any other country, unwarranted disinclinations to use barley, rye, and sorghums as feed are obvious.

It takes quite a time for the producers to get information as to the existence of grains not grown in their locality, the requirements of these grains as to soil and climate, and the

methods of growing. How many introductions of crops failed because either the crop was introduced into the wrong region—as, for example, durum wheat into Kansas rather than North Dakota—or the varieties introduced did not suit local conditions, as happened with rye in the hard-spring-wheat region before the World War. To be satisfactory, the grain mostly has to develop varieties adapted to local soil and climate—an exceedingly slow process until, comparatively recently, men began to learn to attain such adjustments deliberately.

If certain grains have probably penetrated each part of the world to the full extent of their worth and some others have nearly attained this goal, it is largely owing to the fact that migration of grains was accessory to the migration of men. Conquerors brought the major small grains to central and northern Europe. From Europe emigrants took them to America, Australia, and South Africa. They knew how to grow them and also were accustomed to using them. In the past, all cases of *rapid* spreading of grains were those where migration of grains was associated with migration of men. Moreover, such rapid movements have mostly involved not the displacement of one grain by another more adequate, but the use of uncultivated land for the grain brought in by the immigrants. It is evidence of the high properties of corn that human migration did not play a decided role in its spread from its home in America and that corn mostly had to push some other grain from the land.

While it is safe to infer that the process of putting each grain in its proper place has not been accomplished, it is difficult to measure the extent to which the process falls short of perfection. So far as concerns consumption, it is frequently even difficult to say to what extent the cause is lack of knowledge, unfounded stubbornness, as in the cited cases of preference for sorghum as food, or such difference in tastes as for practical purposes may be considered permanent—for example, the preference for wheat and rice in their respective worlds.

Fortunately, if the invasion of rice into the temperate zones of the Occidental world and of wheat into the Orient are dismissed as lacking probability for the foreseeable future, most doubts as to the distribution of grains in the world in the future pertain to the territory not covered in this study. Major doubts pertaining to the latter—on the basis of present knowledge—seem to be whether barley will find its way into the northeastern portion of European Russia's spring-wheat belt, the spring-wheat belt of Siberia, and the wheat belt of Australia, and as to the extent of northern penetration of sorghum, mostly at the expense of corn, in North America and eastern Europe.¹¹

The recent past and near future.—In the past 55–60 years for which more or less comprehensive statistics are available, wheat and rye continued along the previous line. The preference of consumers for wheat bread and their objection to rye bread stimulated this course from the demand side. Steam transportation and development of farm machinery opened up the drier regions to wheat. Progress in other cultural practices, especially the widespread use of lime and artificial fertilizer, and also tariff protection, enabled wheat to hold its position in moister regions and to encroach upon rye territory more rapidly than was possible in the more remote past. While rye, among the grains studied, has shown the smallest increase in world production over the period, world wheat production has made the largest gain.

International trade in wheat expanded greatly in the half-century preceding the great postwar depression, but has severely contracted since, mainly owing to the extreme protectionist measures of deficit countries. Although the proportion of wheat to total international trade in grain declined over the past 55–60 years, the wheat trade still approximately equals the trade in all other four grains combined. International

¹¹ The major uncertainties for the territory not covered in this study apparently involve the extent of further substitution of millets by corn in the Orient and the tropical and subtropical portions of Africa, and the reverse process in the tropical and subtropical portions of America.

trade in rye, which hardly ever exceeded 15 per cent of the trade in wheat, reached its peak around the turn of the century, and is now smaller than it was 25 years before that.

World wheat production is likely to increase in the future at least at the rate of increase in total world production of all grains. World production of rye would probably show a noticeable declining trend in the future, were it not that Germany is making such strenuous efforts to increase domestic rye production through an unprecedented assortment of measures; these include very high rye prices, very high ratios of rye prices to prices of other grains, very cheap fertilizers, and cheap and partly unpaid labor for land improvements. The strong protectionist policies of some other rye-producing countries may also continue to be a factor.

The international situation is unfavorable for expansion of international trade, especially of the trade in grain. Without substantial lowering of protection in most important countries, world wheat imports are unlikely to increase materially in the more or less near future. The world rye trade will probably dwindle into even more insignificance.

The demand for feed grain has increased over the past 55–60 years more rapidly than demand for bread grain. But the production of feed grains—corn, barley, and oats combined—has expanded barely about as much as that of wheat and rye together. In consumption, the deficiency has been offset by a reduction in the proportions of corn, oats, and barley used for food and by enlargement of the proportions of wheat and especially rye used for feed. This shift in demand contributed toward improvement of price ratios in favor of feed grains. Corn, little known in important deficit countries before the period mentioned, has shown the largest relative improvement in price.

In spite of the high yielding power of corn and the improvement in its relative price, world production of this grain has not increased over the past 55–60 years at a rate greater than that of all feed grains combined. Among other reasons, the

United States, the principal corn-producing country, had its corn production relatively well developed prior to that time.

The rate of increase in world production of barley has been almost as large as that of all feed grains. The gains have been primarily in drier regions. Not much land has been taken into cultivation for the particular purpose of growing it, it is true. Wheat frequently showed the way, but barley took advantage of land which proved less fitted for exclusive wheat production, or had become less fitted for such production after having been used for wheat for some time.

Oats displayed the greatest increase in world production from about 1880 to the onset of the era of mechanization of road transport and farm field power. An important reason is that much oats are grown in those portions of the world where huge increases of average yields have been attained by modern intensive methods of crop production. But oats also found access to many newly developed drier regions, invading them with the horse. Since the World War, world oats production could not fail to react to the large decline in the number of horses, their best consumers. But the reaction was confined merely to a discontinuance of the increase in world production, reflecting the firm stand of oats in production.

Corn was the first feed grain to appear in large volume in international markets. But the international trade in oats and especially barley, once started, showed striking increases for some time. The increase in international trade in barley prior to the World War was indeed so rapid that the supremacy of corn in the world markets of feed grains seemed in danger. This rapid rise proved temporary, however, and barley exports are now less than half what they were in the years immediately preceding the World War. The recent development on the demand side has reduced international trade in oats almost to insignificance. International trade in corn meanwhile continued to advance, and in recent years has been more than twice as large as that of oats, barley, and rye combined (Chart 1, p. 1 and Chart 53, p. 459).

The proportion of world grain production used for feed may continue to increase in the future. It is also not unlikely that the proportion of feed grains in total world grain production will advance. On foreseeable grounds, the proportion of barley and especially corn in total world production of feed grain may be expected to increase, while that of oats is likely to decline substantially. A revival of the international trade in oats seems improbable. It would also be very surprising if barley exports ever became even approximately as large as they were before the World War. Corn seems to be the only grain the yielding power of which insures that large quantities will be able to overcome the impediments of high marketing costs from surplus to deficit countries and of tariff protection, so far as the latter is not higher on corn than on other grains.

CHAPTER XVIII

CORN

In discussing individual grains, it was deemed most convenient to deal first with corn and wheat—the grains which mostly are the leading crops in their respective regions and are also the most important among the grains studied in production and world trade. Since in regions well adapted to corn and wheat, corn rather than wheat occupies the predominant position, the discussion begins with corn. Next the choice was between rye, as the crop most strongly competing with wheat in consumption, and barley, which over wide areas competes with wheat more or less strongly for the land and, to a lesser extent, in consumption. Since barley also competes strongly with oats both for the land and in consumption, it seemed slightly preferable to consider barley in the fourth place, immediately followed by oats in the last place.

USES

Corn does not command a particularly high place with the consumer. Although flatbread made from corn compares well with wheat bread in palatability, the use of it in large quantities is in the main limited to poor populations, and is moreover declining. "World" market prices of corn are hardly ever substantially affected by the demand for food use. Corn has some advantages in the use for starch and syrup (corn oil as a by-product), but this use too is an unimportant factor in the determination of corn prices.

The price of corn is commonly "made" in the feed market. Corn is a good all-round feed grain. It may be not quite as good horse feed as oats, but less of it is needed by about 15 per cent. Somewhat less corn than barley is needed to produce 100 pounds of hog; though corn does not produce as good a hog carcass as barley, corn-fed hogs seem to be discriminated against only in a few countries of western Europe.

As a feed for cattle, sheep, and particularly poultry, corn may probably be considered at least as good as any other grain. For some purposes, especially as part of the poultry ration, corn is even superior; but except in such countries as the United States where feeders are very much accustomed to corn, they are seldom prepared to pay for it appreciably more than for certain other feed grains (pp. 54-66).

All in all, "corn at best brings up the rest," as the race-men put it, the first three places being occupied by wheat, malting barley, and rye when rye is evaluated as a bread grain. In world markets corn is usually even the cheapest grain obtainable. This happens partly because the consumers of major importing countries do not accord full justice to its feed value and because some of them are very particular with regard to the quality of their pork and fat backs (chapter iii). But the major reason for the low world prices of corn is that the demand even for the lowest-ranking uses of corn is covered, with a higher return for land use than is obtainable from any other grain.

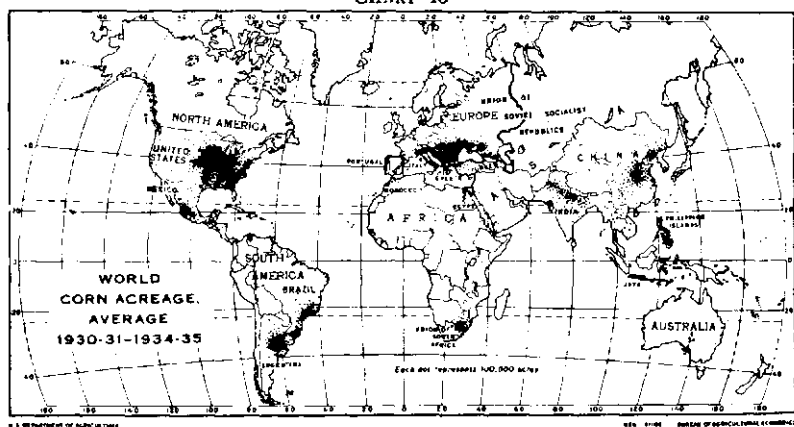
YIELDS AND COSTS

Corn is modest in its requirements as to soil. The only definite need is a topsoil not too heavy and possibly also rather deep for the corn roots to penetrate. But corn is more soil-depleting than the small grains (see p. 233). It is more sensitive to acidity than oats and rye, but is less exacting in this respect than wheat and barley. It is an important advantage of the corn plant that it needs materially less water per unit of total dry matter than any other grain plant considered in this study. The effect of the low moisture requirement, it is true, is materially reduced by the reluctance of corn to make progress with a moisture supply near the minimum permitting life of plants, and by its tendency to develop relatively much stalk in the same conditions. Sorghum and other millets, however, need even less moisture per unit of dry matter than corn, and also otherwise surpass corn (or any other grain) in ability to thrive when moisture is at the bare minimum.

In contrast to the moderate requirement of corn as to soil, and its low moisture requirement, are its rigid requirements as to temperature. The high minimum germination temperature of corn, its relatively long growing period, the large amount of warmth needed (both warm days and warm nights up to ripening are important), and at the same time its refusal to make good progress at very high temperatures (particularly in the absence of sufficient moisture in soil and air), greatly limit the area where corn can be grown in the world successfully (see chapter xi and Chart 48).

Provided the rigid requirements of corn as to temperature are satisfied, corn greatly excels all other grains here studied in yielding capacity. Where corn is at its best and the methods of crop production are extensive or only moderately intensive, corn yields approximately twice as much as wheat and outyields the coarse small grains by nearly as much. Corn remains greatly superior in yielding power to other grains even far outside of the regions with climatic conditions most favorable to it. But in regions poorly to moderately supplied with moisture and sufficiently hot for sorghum, this grain outyields corn sensibly to heavily. Provided its climatic requirements are fully met, corn shows the best response in yield to

CHART 48



applications of manure, to legume predecessors, and the like; but the ratios between the yields of corn and other grains in general become less favorable to corn as the application of fertilizer in every form is enlarged. The change is particularly marked where temperatures are only moderately satisfactory to corn.

Except in some drier regions, the per-acre cost of producing corn is higher than the cost of wheat, the small grain which usually has the biggest per-acre costs in such conditions. Where grains are produced very intensively, the per-acre cost of corn may exceed that of wheat by as much as 40 to 50 per cent. This extra outlay is in part simply the result of the larger yields of corn, and in any case is overcompensated by the heavier yield wherever weather conditions are even moderately favorable to corn. Where corn is at its best, it costs about 60 per cent as much to produce as wheat and about 70 per cent as much as the next cheapest coarse grain (pp. 412-13).

WORLD PRODUCTION AND PRODUCTION REGIONS

With the favorable showing of corn in yield and cost, it is only natural that, wherever its peculiar requirements with regard to temperature and moisture are met, this prolific plant plays the dominant role in production. With the price ratios between corn and wheat as they have been for half a century, even wheat had to give way before corn in regions climatically best adapted to corn, wherever the combination corn-wheat in the same rotation did not prove preferable. The superiority of corn in yielding power was stronger than the price superiority of wheat.

But continuous growing of corn in the important corn regions gives best results only for a relatively short time. Growing it in rotation is usually preferable, owing to both higher yields and managerial advantages. Where, as in Argentina, most of the corn-growing portion of Europe, and part of the corn-growing portion of the United States, temperature con-

ditions make it possible to seed winter wheat in time after corn, the combination corn-winter wheat (with or without a hay crop as a third member of the rotation) has large economic advantages on soils adapted to wheat growing (combination of the highest-priced and highest-yielding grains). But in large parts of the United States adapted to both corn and wheat, and to some extent also at the northern border of corn cultivation in central and eastern Europe, the warm season is too short for timely seeding of winter wheat after corn. More or less far-reaching rearrangements therefore become necessary. In the heart of the Corn Belt, winter wheat is mostly omitted from the rotation. Outside of that region, compromises are sought in harvesting corn in a more expensive but speedier manner, delaying somewhat the seeding date of winter wheat, or both; seeding wheat between standing stalks of corn; extending by one year the rotations corn-spring-sown small grain-hay, or corn-corn-spring-sown small grain-hay, and placing winter wheat before hay; or resorting to such rotations as corn-corn-winter wheat, corn-corn-winter wheat-winter wheat, and the like.

Where in "corn climate" winter wheat cannot follow corn and a spring grain has to be inserted after corn, oats usually get the choice; but as little oats or other spring grain is grown as is consistent with good crop management.

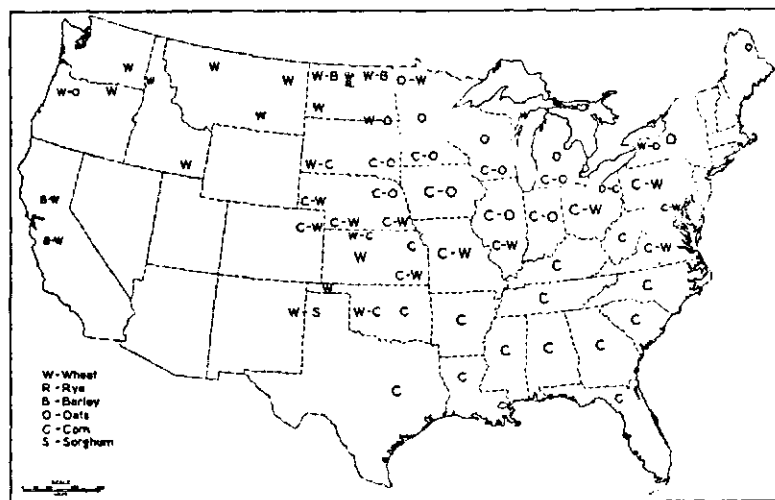
The rigid limitations imposed on corn growing by temperatures, and partly by moisture, bring it about that the acreage in this prolific crop in the world (ex-China) is sensibly less than the combined *acreage* of barley and oats; while world corn production is approximately equivalent to the combined *production* of the latter. Even though the average per-acre yield of wheat is lower than that of any grain here studied, while the yield of corn is highest, world production of corn is about 20 per cent less than that of wheat.

The United States.—The United States is the only country in the world where the specific temperature and moisture requirements of corn are met over a very wide contiguous

territory. Hence approximately half the world acreage and production of corn are found in this country (see Chart 48 and Tables I and II). Chart 49 shows that in every region east of the Great Plains, except for the northern strip which is too cold for corn, this grain is either the only important grain crop or the leading crop with another grain as runner-up.

As in Charts 51, 56, 58, Chart 50 compares the relative prices of specified grains with their relative costs of production. These are computed as far as possible at uniform rates and must be used cautiously. (For a detailed discussion of methods of computing costs at uniform rates and their possible uses, see Appendix Note C.) Provided the necessary precautions are taken, the comparison of the relative costs

CHART 49.—GEOGRAPHICAL DISTRIBUTION OF LEADING GRAINS IN THE UNITED STATES, 1929*



* Based on census data for 1929, this chart shows for each region (1) the grain crop which had the largest acreage harvested for grain among cereals; and (2) the grain crop with the next largest acreage harvested for grain where its acreage was equivalent to not less than approximately 20 per cent of the total cereal acreage harvested in that region for grain. The key letters are inserted roughly in the center of the regions or sections to which they pertain; large blank spaces indicate regions where grain production is very small or negligible.

The writer is indebted to Dr. O. E. Baker, Bureau of Agricultural Economics, U.S. Department of Agriculture, for valuable suggestions in connection with this chart.

with relative prices permits one to get a rough idea as to which crop may be expected to occupy the largest acreages and which will not be grown at all or will have to rely for a moderate place in production on their usefulness as rotational crops or the need of the farmer for them for his own use.

As shown by Chart 50, the cost of production of corn relative to its price in the heart of the Corn Belt is so favorable that corn, to dominate fully, does not need even the additional advantage of being converted into animal products on the farms producing it with the ensuing profit thereon. In a portion of the Corn Belt, farmers in fact find it more profitable to concentrate on growing as much corn as possible as a cash crop. Most of the corn shipped to markets in the United States indeed originates there.

Provided the soil is suitable for wheat, however, the superiority of corn over wheat in profitableness is not very large, and even in areas best adapted to corn, wheat remains a strong potential competitor for acreage. In type-of-farming region VI in southwestern Illinois, for example, natural conditions are somewhat more favorable for wheat and for the combination corn-winter wheat than in the central and northern parts of the state, and the acreage in wheat jumps to 21 per cent of the tillable land (1929), being practicably as large as that

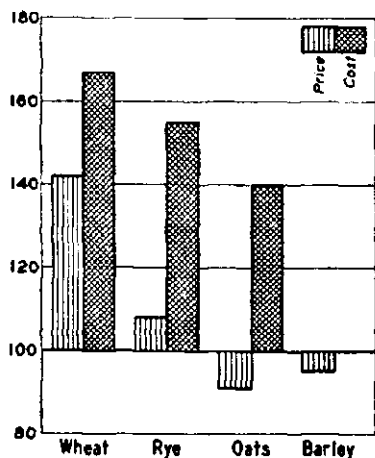


CHART 50.—RELATION BETWEEN PRICE RATIOS AND COST RATIOS OF SPECIFIED GRAINS, IN THE HEART OF THE CORN BELT*

(Price or cost of corn = 100)

* Ratios between average farm prices in Iowa and Illinois in 1922-31. Ratios between average costs of production in 1922-31 in Iowa and Illinois, as shown in Table 25, p. 411, supplemented by considerations in the text; see footnotes *d* and *e* to that table for comments on the character of the cost data.

of corn.¹ During the World War the price ratios were more favorable to wheat than in 1922-31 (the years used in Chart 50), and the wheat acreage of Illinois was doubled in a few years.

Oats in the heart of the Corn Belt do not compete with corn, but are produced because they fit best with it in rotation. Produced in excess of the amounts required for insuring to corn the advantages of rotation, especially of having a hay crop together with it, oats would involve a large loss.

The price of barley as shown in Chart 50 may appear to justify replacement of some oats by barley (assuming that on certain farms barley can be grown for only slightly more per cental than oats), but the price of barley shown in the chart was relatively high only because little of it was grown. A large production would have brought the barley price down to or below that of oats, unless the barley could find a market for malting purposes.

The cost of producing rye for grain on good lands of the Corn Belt is little if any less than that of wheat, while the price is much lower. The small acreage in rye found there is destined primarily for late fall and early spring pasture, and only what is left is harvested for grain needed as seed.

West and southwest from the heart of the Corn Belt, price ratios tend to become more favorable for wheat, because increasing distance from the deficit markets favors wheat, the higher-priced grain, and the quality of wheat also becomes more desirable. The cost ratios, on the other hand, show a tendency, at first weak but later stronger, to become less favorable for corn. Since the advantage of growing corn rather than wheat is not very substantial even in portions of the heart of the Corn Belt, the regions are soon reached where wheat is as profitable as corn, or even more so.² But corn retains a strong position as a subsidiary crop over a wide area

¹ H. C. M. Case and K. H. Myers, *Types of Farming in Illinois* (Illinois Agr. Exp. Sta. Bull. 403, June 1934), p. 183.

² The area where corn remains more profitable than wheat, or not less profitable, is extended by the utilization of corn and other feed grains on the farms that produce them.

owing to the better utilization of power and labor as compared to that attainable on farms producing small grains only, and also, on land unadapted to winter wheat, to the improvement in yields of small grains following corn in the rotation.

The price and cost relationships for North Dakota shown in Chart 58 (p. 484) indicate that corn is superior even to wheat in profitableness.³ This superiority may be present—even this is rather doubtful—only in the southeast of the state where the climatic handicap to corn growing is somewhat less. In any case it does not pertain to corn grown for grain. The rather substantial acreage in corn in that portion of the state (Chart 59, p. 484) is mainly harvested for silage and fodder, hogged down, or grazed off.⁴ Over the bulk of the state even such acreages are sparse, owing to shortness of the frost-free period.⁵

Moving south from North Dakota, corn is favored by the lengthening of the frost-free period, while spring wheat is handicapped by the increasing summer heat. The escape of wheat by a shift to winter wheat in Nebraska seems not to improve the position of wheat substantially, because the climate is not very favorable for it. The competitive position of corn against wheat in southern South Dakota and most of Nebraska, in fact, is apparently almost or quite as strong as in the heart of the Corn Belt, especially on land less adapted to wheat. Ratios between yields somewhat less favorable to corn (see wheat yields expressed as percentages of corn yields in Chart 43, p. 302) are approximately offset by ratios between costs per acre more favorable to it. The corn acreage, indeed, exceeds the wheat acreage in every crop-reporting district of the southern two-thirds of South Dakota, and in all of Nebraska, except one northwestern district which includes a large pro-

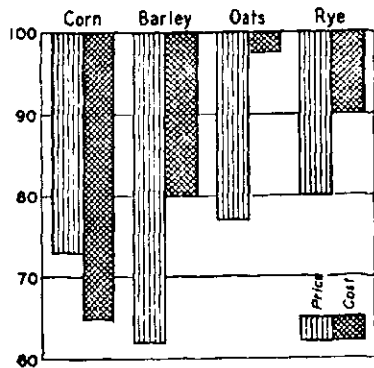
³ If the chart were not based on data for the state as a whole, the price ratios would probably be somewhat less favorable to corn.

⁴ See the four charts in O. E. Baker and A. B. Genung, *A Graphic Summary of Farm Crops* (U.S. Dept. Agr. Misc. Pub. 267, March 1938), pp. 16, 17.

⁵ This is apparent from Chart 59 (p. 484) showing acreage in all corn, i.e., harvested for grain, silage, and fodder, hogged down, or grazed off.

CHART 51.—RELATION BETWEEN PRICE RATIOS AND COST RATIOS OF SPECIFIED GRAINS, IN KANSAS*

(Price or cost of wheat = 100)



* Ratios between farm prices in 1922-31. Ratios between costs of production in 1922-31 as calculated on pp. 398, 407; ratios between the costs of production of corn and small grains are valid, if at all, only for eastern Kansas.

portion of irrigated land (Chart 44, p. 303). In Nebraska sorghum makes its appearance as a competitor of corn; it is as yet rather weak but may become stronger as time passes.

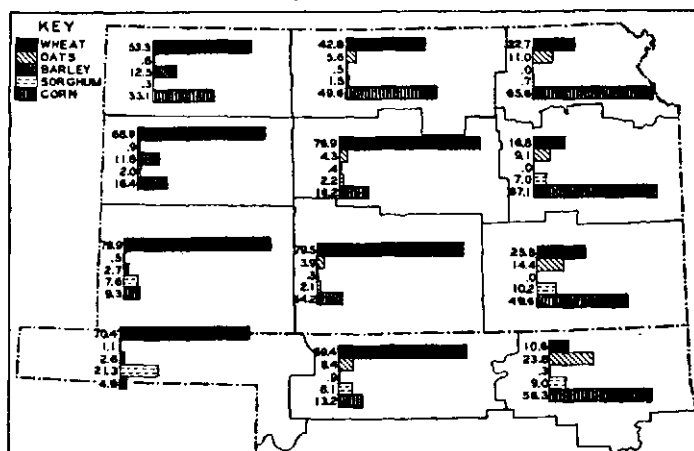
Important changes come as we move farther south into Kansas. The increasing dry summer heat becomes burdensome to corn and simultaneously strengthens the competition of sorghum. As with North Dakota, price and cost relationships based on data for the whole state indicate that corn is more profitable than any small grain (Chart 51). But this is likely to be true only for eastern Kansas. Chart 52 shows that while corn is still predominant here, it has to give way to wheat in central and western Kansas; and in southwestern Kansas and farther south it is definitely replaced by sorghum.⁶

The Mountain states are in general too cool for corn. Hence it plays only a moderate role, though (and therefore) price ratios to wheat are much more favorable to corn than in the Corn Belt. On irrigated lands located mainly in these states, corn—aside from being hampered by temperatures—fits poorly into the rotations with the most profitable crops of such lands. The larger yielding capacity of corn nevertheless

⁶ See also Charts 43, 44, 48, and 49, and Table 25. The acreage in sorghum in 1929, on which Kansas data in Chart 52 are based, was exceptionally low in the state as a whole. Moreover, were the feeding value of sorghum appreciated by feeders in full, the relative proportions of acreage in corn and sorghum in Kansas, Nebraska, a portion of Missouri, and some other sections would be materially more favorable for sorghum.

CHART 52.—RELATIVE ACREAGE IN SPECIFIED GRAINS, BY CROP-REPORTING DISTRICTS, IN KANSAS AND NORTHERN OKLAHOMA*

(Total grain acreage = 100)



* Harvested acreage: 1929, for Kansas; average of 1923-32, for Oklahoma. For small grains and sorghum, acreage harvested for grain; for corn, total acreage.

assures corn some place where it is important to get the largest tonnage from a given area.

Southward and southeastward from the heart of the Corn Belt, the proportion of the grain acreage occupied by corn becomes ever larger. The cost of producing corn, it is true, increases more rapidly than that of the other grains. But corn remains cheaper to produce than any other feed grain—except perhaps sorghums in some places. Corn does not even need oats as a companion in the rotation; this grain—increasingly hampered by heat—drops almost suddenly out of the picture (see Chart 35, p. 268). This leaves corn the only important feed grain and in fact the only important *grain* produced, for wheat too does not prove able to compete with corn on the rather poor soils of these regions at the price ratios between these two grains much more favorable to corn than in the Corn Belt.⁷

⁷ The improvement in relative cost of producing wheat is insufficient to offset the larger increase in price of corn.

To the east of the heart of the Corn Belt, on the other hand, the paradoxical phenomenon of a revival in the competitive power of wheat can be observed (see Chart 27, p. 245), in spite of the fact that the price ratio becomes increasingly less favorable for wheat and the soil less adapted to it.⁸ The ratio of corn acreage to wheat acreage is about 35:1 in Iowa, 5:1 in Illinois, 3:1 in Indiana, less than 2.5:1 in Ohio, only 1.3:1 in Pennsylvania, and 2.5:1 in New York. One of the reasons for the strong increase in the significance of wheat is the less favorable climate for corn and consequently the smaller profitableness of corn growing.⁹ Also, the decreasing proportion of total acreage in corn and the somewhat milder climate make the strong combination of corn-winter wheat more practicable in the eastward movement. On the one hand, stover becomes more valuable and is commonly saved in the east in the speedier way of cutting the whole plant and removing it from the field; on the other hand, the milder climate makes early seeding of wheat less urgent than it is in the heart of the Corn Belt. With wheat placed directly after corn, it usually can claim a remuneration for service as a cover crop, since hay is regularly the third in the party. Still, in general, wheat merely pushes itself into a more prominent position as a crop subsidiary to corn, which remains the leading crop.

Argentina and South Africa.—The corn belt of Argentina is almost a tiny spot compared with the corn-growing area of North America (see Chart 48, p. 446), yet it is of paramount importance to the world grain market. Without doubt, Argentine corn is the grain most cheaply produced in the world.

⁸ The farm price of corn in per cent of the wheat price was 67 in Iowa and 80 in New York in the crop years 1925-29, and 78 and 93, respectively, in 1932-36 (Chart 2, p. 10).

⁹ This decline in profitableness of corn is reflected in the fact that, according to our computations, the advantage of corn in cost of production dwindles in the eastward movement more rapidly than its advantage in price. The cost of producing wheat in the heart of the Corn Belt was assumed to exceed that of corn by approximately 65 per cent (Table 25, p. 411); at the other end, in New York state, it seems to be only about 15 per cent more (p. 409). Oats produced in the heart of the Corn Belt in large quantities for their own sake, and not out of rotational considerations, would cost about 40 per cent more than corn; in New York state the additional cost probably does not exceed 10 per cent.

Much corn is grown there on soils greatly enriched by growing alfalfa for several years in succession. Without application of manure, yields are secured in the better portions of the belt which far exceed those obtained in Rumania and are almost comparable with the yields obtained, with considerably more effort, in the best parts of this country. Finally, no other important surplus country can ship its corn to the north European importing markets as cheaply as Argentina can.

Argentine wheat too is inexpensive to produce and to ship to importing markets. Corn nevertheless proves a very strong competitor for acreage. As shown in Chart 2 (p. 10), corn prices in Buenos Aires averaged in 1932-36 68 per cent of the average wheat price. Since the railway rate on corn is lower than that of wheat by about 15 to 20 per cent (p. 548), the farm price of corn may be assumed to have averaged about two-thirds of farm price of wheat. But corn costs only about 60 per cent as much to produce as wheat (Table 25, p. 411), perhaps even somewhat less. Moreover, probably no substantial decline in yield occurs if corn is the only grain crop grown on alfalfa land. Corn actually expels wheat from the land best adapted to grain growing except for the year in which a small grain is needed as a cover crop (see Chart 43, p. 302). Wheat production on a large scale starts only west and south of the principal corn zone. Even there, owing to its rotational and managerial advantages, corn is able to retain an important position as a crop subsidiary to wheat.

In many regions of the world, the gain from feeding the grain on the farms producing it is important in strengthening the competition for the land of feed grains with wheat. Such gains cannot have much significance in Argentina, owing to the character of its livestock industry. Argentine corn holds its strong position though it is almost exclusively a cash crop. This strength was demonstrated during the recent depression, when Argentine corn was the only major export grain the production of which expanded greatly.

Corn is very important in the economy of the Union of

South Africa both for domestic consumption of man and beast as well as for export. Indeed, it far exceeds in significance all other grains combined.¹⁰ But natural conditions in the Union are very unfavorable for the production of any grain, and corn does not constitute an exception. The principal limiting factors are the inadequate and/or poorly distributed rainfall coupled with large evaporation, extreme year-to-year variations in precipitation, and low fertility of the soil (insufficiency of phosphates).¹¹ The average corn yield in the Union (Europeans' crop), on the average of 1932-36, was only 5.2 cents per acre, while it was 9.4 in Rumania, 11.8 in the United States, and 16.2 in Argentina (Table III). The corn exports that the Union was able to build up in years of more or less satisfactory prices in world markets were possible only owing to very cheap labor,¹² and in recent years, exports on a reduced scale (Table V) could be maintained only by subsidies. The leading persons in the Union are perfectly aware that South Africa cannot compete with other more fortunate countries in the world corn market.¹³

Europe.—Of the limited area in Europe which is not too cold for corn, a substantial portion has the so-called Mediter-

¹⁰ The only competition encountered by corn in the territory with summer rains is that with sorghum in regions with little precipitation. Some encroachment of wheat became possible only after protectionist measures had raised the price of wheat to twice the corn price.

¹¹ A. R. Saunders, "Problems in Maize Production," *Farming in South Africa*, September 1933, VIII, 327.

¹² "Native laborers are paid only \$5 to \$10 per month, and a considerable number work for no wages other than the right to live and graze their livestock on the European owner's farm." C. C. Taylor, *Agriculture in Southern Africa* (U.S. Dept. Agr. Tech. Bull. 466, March 1935), p. 317. See also F. R. Tomlinson, "The Business Side of Peanut Farming. III. Costs and Profits in the Production of Peanuts, Maize and Tobacco," *Farming in South Africa*, November 1936, XI, 459-60.

¹³ See, for example, the "Annual Reports of the Secretary for Agriculture" for recent years in *Farming in South Africa*. In his report for the year ending Aug. 31, 1935, the Secretary wrote: "We have seen that the Government is doing everything in its power to keep the maize industry on its feet, but I must candidly admit that these measures [guaranteed prices for maize] cannot but be regarded as palliatives and that they provide no satisfactory solution of the problem." "As I see the matter, the task of the maize farmer would seem to resolve itself into an orderly retreat from the present system of production for export in the grain form . . ." *Farming in South Africa*, December 1935, X, 496.

anean climate, with practically no precipitation coming right at the time when corn is grown. In another, although having summer rains, precipitation is too scanty. But corn fills almost every hole left open for it by the insufficiency of warmth and the drought.

Only five per cent of Spain's total grain area was in corn in 1935 (Chart 53), yet in the northwestern corner at the Atlantic (Coruna, Oviedo, Pontevedra)—the only portion of Spain with substantial summer rains—more than three-quarters of the acreage was devoted to that grain. Similar are the conditions in Portugal. In France, corn finds a refuge only in the southwestern corner (Pyrenees Basses and Landes), owing again to climatic conditions; but there it dominates, in spite of the exorbitant protection bestowed upon wheat. The whole south of Italy is closed to corn by the summer drought, but corn plays a significant role in the north—apparently to some extent on irrigated land—and would be still more important there were not wheat the favorite child of Italy's protective policy (the *battaglio del grano* is in fact *battaglio del frumento*).

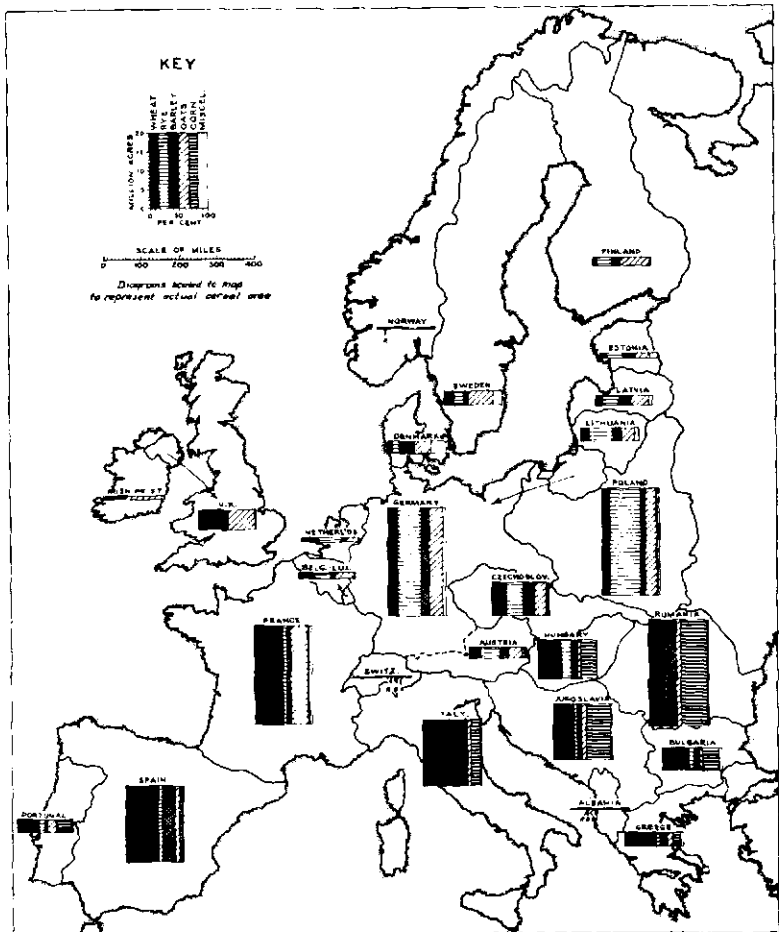
Only a small portion of the Danube basin is affected by summer drought, and corn at once springs up as the dominant crop in a large part of the basin. Precipitation is not large enough for the best yields of corn, it is true,¹⁴ but the warm season is commonly long enough to permit the timely seeding of winter wheat after corn. While on soils not well adapted to wheat, corn frequently is grown continuously, the combination of corn-winter wheat is almost exclusively followed on better soils. The rotation becomes corn-corn-wheat where corn is more profitable or more needed for use on the farm, and corn-wheat-wheat where wheat has the edge.

Soviet Russia has made strenuous efforts to expand corn acreage up to the temperature limit, but encounters a great obstacle in the scarcity of moisture. After the rather conspicuous

¹⁴ In certain portions of the region, also, the technique is not quite up to date (only one to two cultivations).

gains in the 1920's and a moderate further increase in the early 'thirties, a large decline in corn acreage took place—

CHART 53.—ACREAGE IN SPECIFIED GRAINS IN EUROPE EX-RUSSIA, BY COUNTRIES, 1935*



* Basic data from *International Yearbook of Agricultural Statistics, 1935-36 and 1936-37*. The several blocks of bars are proportionate to the total grain acreage of each country. Hence the area of each block may be considered the total grain acreage, and the area of each bar the acreage in the designated grain, of the country in which it appears. Moreover, since the several blocks of bars are uniform in width, the proportions of each grain to total grain acreage in different countries may be readily compared by comparing the width of the bars for that grain.

from 9,418,000 harvested acres in 1930-34 to 6,618,000 acres according to the plan for 1937. The decline may prove temporary. The former expansion took place under extreme pressure, without regard to availability of adapted varieties and to lack of knowledge on the part of peasants as to how to grow, harvest, and preserve corn.

North of southern France, Italy, and the Danube countries, insufficiency of warmth is the principal obstacle to the penetration of corn. So far as corn is not entirely barred, warmth is just barely sufficient for silage rather than for corn grain. But as a source of bulky feed, corn, a relatively intensive crop in the conditions of the United States, proves insufficiently intensive in the more northern portions of western and central Europe where such really intensive crops as beets and potatoes are grown on a large scale for feed. Corn is particularly unadapted to small family farms making extended use of the labor of female family members. Under such conditions corn growing would be hampered by its bad fit in rotation with other row crops, even if climate permitted its cultivation for grain.

World production in the past.—In spite of the large advantages of corn, world (ex-China) production of this grain increased in the past 55-60 years for which more or less summarized statistics are available by only approximately as much as the total world production of all grains covered in this study.¹⁵ The principal reason is that the most important region climatically adapted to corn, North America, was widely used for this grain before that time. Production in the United States moreover recently suffered greatly from drought and was reduced by governmental regulation as well. Although no corn is produced in northwestern and north central Europe, where the greatest increases in yields have been attained by intensification of the methods of crop production, world production of corn ex-China *ex-United States* increased over the 55-60 years at the same rate as, or more than, that of any other grain here studied.

¹⁵ For sources of these data, see p. 496.

WORLD TRADE

Corn was the first feed grain to reach the deficit countries in large volume in the early days when international trade in feed grains began. On the average in 1878-82, nearly 2,500,000 short tons were brought to European importing countries from the most important transoceanic countries and Russia. The imports of oats amounted to about 900,000 tons and those of barley to only 500,000 tons at that time. Thus trade in corn was nearly twice as large as in oats and barley combined. This ratio between world trade in corn and that in other feed grains was maintained until the turn of the century. Imports of corn increased by about 125 per cent and imports of oats by 80 per cent, but the difference was made up by the large increase in imports of barley, which nearly quadrupled in the twenty years from 1878-82 to 1898-1902.¹⁶

The turn of the century, however, proved also a turn in the world trade in feed grains. The large expansion of industrial activities in western Europe necessitated continued growth in feed imports. The strong rise of feed-grain prices in the first decade of the present century was proof of the urgency of this demand. Although the additional requirement was primarily for hog feed, exports of oats from important surplus countries increased by about 35 per cent in the eleven years from 1898-1902 through 1909-13. Exports of barley, continuing their previous sensational rise, advanced by not less than 130 per cent over the same short period. But corn failed to make any use of this opportunity.

In the second half of the nineteenth century the United States was the principal source of export corn. At the turn of the century, when the share of the United States was already contracted by the competition of other surplus countries, more than 60 per cent of the world exports of corn still originated in this country. The rapid expansion of corn acreage in the highly productive regions of the United States in

¹⁶ Data from *Das Getreide im Weltverkehr. Statistische Tabellen über Produktion, Handel, Konsum und Preise* (Austria, Ackerbauministerium, 1900, 1905).

the last quarter of the nineteenth century resulted in a rate of increase in production which could not be entirely absorbed by the domestic market. Since most European countries were not acquainted with corn, the surplus had to be dumped at prices extremely low relative to those of the other feeding grains. It is, however, important to point out that, even though the exports of corn from the United States were immense from the point of view of importing markets not accustomed to its use, they constituted only a small percentage of domestic production in the United States. With a slightly lower rate of expansion of the corn acreage, the exports might barely have covered the urgent needs of importing countries. Hence the slower rate of development of the corn area in the twentieth century, reinforced in its effect by the rapid industrial expansion, brought it about that in 1909-13 exports of corn from the United States averaged only about one-third of those of 1898-1902. But for the strong advance of corn prices, and the fact that the large gap between the prices of corn and the other feed grains was almost closed by the time immediately preceding the World War, even those greatly reduced quantities might have been retained at home.

The balance of the net world exports at the beginning of the twentieth century was in the main supplied by three countries—Russia, Rumania, and Argentina. Both European countries were unable to take much advantage of the favorable situation created by the rapid withdrawal of the United States in the ensuing years, for the export possibilities of these countries were already well utilized at the end of the nineteenth century. A few other countries, it is true, entered the market as exporters at that time. A prominent place on the world markets had been prophesied for British South Africa by enthusiastic domestic and misguided foreign students, but in the last prewar years its corn exports averaged barely 100,000 tons. Under such conditions the vacant role of the principal corn exporter was fully taken by Argentina, also almost a newcomer to the world corn markets.

Argentine corn exports averaged slightly over a million tons in the five years centered around 1900. Only the phenomenal cheapness of corn production there could make it possible that an entirely undeveloped country, such as Argentina then was, could have exported so much in competition with the dumped exports of the United States. When this competition weakened in the new century, thinly populated Argentina was able nearly to treble its corn exports in a decade. Almost 50 per cent of world imports of corn was Argentine corn in the years immediately preceding the World War.

Yet the immense development of Argentine corn exports could not keep pace with the contraction in American exports. Total world exports of corn declined in the prewar period of the twentieth century, with the result that barley with its rapidly expanding exports came within striking distance of overtaking corn. It might have appeared from the observation of statistics of world exports that, with a few years more of such development, corn would be relegated to second place among the feed grains in the international trade.

Developments of the world market in feed grains in post-war years showed important new features particularly with regard to the trade in oats and barley (see Table V and Chart 54). Oats as an object of world trade succumbed under the competition of motor fuel. The withdrawal from the world markets on the part of Russia, which supplied about 70 per cent of the prewar exports of barley and only 12 per cent of those of corn, was a heavy blow to the world trade in barley from which it never recovered. For a time it might have seemed that the United States and Canada were going to capture the place on barley import markets released by Russia; but the exports of the United States were to some extent the result of prohibition. In any case, they have now been discontinued, except for some California malting barley which had also been exported before the World War. Barley exports from Canada also did not stand the severe test of the recent depression, and became almost insignificant in recent

years. Droughts may have had something to do with this phenomenon; but the marketing costs from the Canadian prairie, especially on oats, are so high that Canada is unlikely to be a permanent exporter of large quantities of coarse grains, except at such prices as cannot be expected in peace time. Even in the postwar prosperity years, Rumania could not export as much barley as had been exported before the World War by the territory now forming that country. In the ensuing depression, exports from Rumania dropped heavily. Total world exports of barley in postwar years at best slightly exceeded half of the prewar exports and recently averaged less than two-fifths.

The United States virtually dropped out of the picture as a corn exporter. The Union of South Africa made good but not overwhelming progress by increasing her exports to an average of about 500,000 short tons in the years preceding the depression. The disaster of the early thirties, however, was too much for that country, which even in good times could compete only because of extremely low wages. Rather heavy subsidizing of corn exports by the Union in recent years could not prevent a considerable falling off. In spite of a substantial expansion of the corn area, corn exports of the densely populated Danube countries in postwar years never reached the prewar level and have shown a further decline in recent years. All these not very promising developments notwithstanding, world exports of corn in the postwar prosperity years were materially larger than in the prewar years; moreover, in the ensuing disastrous years they were not only maintained but frequently exceeded. The answer to this surprising phenomenon is Argentina.

Argentina easily overcame the setback experienced by her corn exports during the World War owing to insufficiency of tonnage. In the five years ending with 1929-30, Argentine corn exports averaged nearly twice as large as in the last prewar years. That country alone exported in those years almost as much corn as all exporting countries of the world,

crease in her exports. As usual, the depression helped the strong to shake off the weak. In the last few years (Chart 54), Argentina exported much more corn than all other countries combined could bring to foreign countries of corn, barley, oats, and rye together. The cheapest kind of grain from the cheapest producer smashed all its competitors.

A final remark seems in place here. Corn exports originate almost exclusively in moister regions, exports of small grains preponderantly in drier regions. The moister regions are in general located somewhat the more favorably as to import markets. The Argentine corn area is in a particularly favorable position in this regard. Corn furthermore has some advantages over barley and oats in marketing costs from the same places. Yet all these advantages are hardly very significant for the dominating position of corn in the world exports of feed grain. Under normal conditions, somewhat higher marketing costs would merely lower the usually high prices of the land well adapted to corn. But in such periods of extremely low prices as the one since the recent depression, the difference in marketing costs may have played a part in the outcome of the struggle for preservation.

OUTLOOK

While the use of corn for food may gain some new ground where the alternative is millets—mainly in the Orient and central and southern Africa—this increase may be offset by declines in other regions. But the recognition, outside of the regions where corn is native, of the feeding properties of corn grain, corn fodder, and corn silage, which has gained visibly in the twentieth century, is likely to make further progress. The changing attitude of feeders in European importing countries is particularly pertinent in this connection.

The limited extent of land climatically adapted for corn will continue to be an important obstacle to the expansion of corn production, in spite of the great yielding power of this grain. The competitive power of corn may also be adversely

affected by the fact that corn is more soil-depleting than the small grains (see p. 233), especially in drier regions such as Kansas or parts of Argentina where little leguminous hay is grown and where crops do not repay the use of manure or fertilizer. In the United States, the government pays for the inclusion of soil-building crops in the rotations. It is not improbable that at some future time—here and/or abroad—the proportion of soil-depleting crops—that of corn more than those of small grains—will be restricted by law. The spread of the combine for harvesting small grains may be a further factor impairing the competitive power of corn; its effect will probably not be fully offset by the support which corn production gets from the mechanical corn picker. The unfavorable prospect for enlarged production of any grain in the United States will be most strongly reflected in world production of corn. Encroachment of sorghums in the United States, and perhaps also in some other countries of the Americas, may continue.

On the other hand, hybrid corn may prove a powerful factor accelerating expansion of corn production in the immediate future. It and/or the increasing appreciation of corn as feed will enable it to expand in regions where a point of saturation was reached at previous relative yields and relative prices, and—even more—in regions where corn did not previously occupy the place it deserves. Should the use of corn as food in the Orient and Africa increase, this would of course also mean greater production there. The ultimate balance of the pros and cons is difficult to foresee. But the proportion of corn production to total world grain production is unlikely to increase sensibly unless the rapid rise of grain yields in northwestern and north central Europe, from which corn does not profit, should materially subside in the future.

The dominant position of corn in world exports of feed grain is unlikely to be altered. World trade in oats seems to be doomed forever. Exports of feed barley are more likely to decline than to increase. Russia hardly will again become

an important factor in the world barley market, even if the plans for further contraction of barley production (see p. 526) should fail. Other exporting countries are unlikely to find it profitable to increase their barley exports considerably.

Whether world imports of corn will continue to advance and, if at all, at what rate, depends on many circumstances (especially trade barriers) which cannot be forecast. Some further increase seems probable nevertheless. Argentina is likely to continue to have almost a monopoly of the market as an exporter. Corn production in the Danube countries and perhaps also in Russia will expand, but the extra quantities may be absorbed for domestic needs. Sooner or later, British South Africa will discontinue its corn exports by shifting to more animal production. The United States can reappear as a permanent corn exporter only under a two-price system or its equivalent. But Argentina will hardly have difficulty in increasing her corn exports further, even without a material improvement in corn prices relative to the prices of the other grains. Yet owing to the advancing recognition of corn as a feed grain, a further rise of corn prices in terms of prices of other grains on world markets is likely. Such an improvement of corn prices may fail to materialize only if import requirements should be kept materially and continuously below the export possibilities of exporting countries, primarily those of Argentina.

CHAPTER XIX

WHEAT

USES

With much justification, wheat is frequently referred to as the only *true bread grain*. Rye is the only other grain the dough of which possesses the ability to expand under the influence of gases, but in this it is much inferior to wheat. Wheat bread is also more easily digestible than rye bread. The overwhelming majority of consumers outside of the rice-eating world show a definite preference for wheat bread as the principal form of cereal consumption. So far as goods made of any other cereal retain the position of the principal cereal product, cheapness rather than liking is the cause. Wheat therefore is the only grain of which large quantities find a demand at much higher prices than those paid for large quantities of other grains except rice, not included in this study, and malting barley.

High-protein wheats grown on former grassland soils in drier regions (referred to also as hard or strong wheats) yield a large loaf with a fine texture. If, on the other hand, the bread is produced of wheats grown in moister climates, especially those produced with the application of large amounts of fertilizer, the volume of the loaf is small and its texture rather poor. More or less substantial premiums are therefore paid for high-protein wheats. The Prairie Provinces of Canada, the hard-spring-wheat and hard-winter-wheat regions of this country, and almost all wheat regions of Russia produce high-protein wheats. Argentina has softer wheats, while Australia produces an excellent wheat of medium strength and white color (all wheats mentioned earlier are red in color). Northwestern and north central Europe grow the weakest wheats.

According to its content of nutrients, wheat is superior to

all other grains in use as feed, but is less digestible to livestock than corn, barley, or oats. Wheat, especially high-protein wheat, if fed without due care, is likely to induce colic. It is therefore used to best advantage mixed with other grains. Feeding wheat to horses must be done with special care. The largest amount of wheat used as feed in a normal year is consumed by poultry. In several areas as, for example, Great Britain and many regions of the United States, wheat seems even to command material premiums over the prices of other feed grains for use as an ingredient of the "scratch mixture."

YIELDS AND COSTS

Wheat is the most exacting grain with regard to soil requirements. It yields relatively best on soils with a high content of humus and rich in nutrients readily accessible to plants. The nutrients, it is true, can be provided in the form of fertilizer on many soils. Large humus content also is not absolutely indispensable. But on sandy soils wheat refuses to grow. It is more sensitive to acidity than any other grain save barley. It surpasses rye in response to cultural practices, especially to application of manure and fertilizer. Winter wheat, which responds more vigorously to these than spring wheat, is also superior to spring oats in response to many practices. The response of winter wheat to some important practices is considerably less than that of corn in "corn climates"; it also often proves inferior to spring barley and less frequently to spring oats. But no other grain can be grown so intensively as winter wheat. This fact, as well as the higher price which makes wheat more able to repay cultural practices, frequently more than compensates for the inferiority of the response of wheat to such practices. No other grain indeed has gained so much in competitive power from intensive cultivation and the application of science to agriculture in general (chapter xiii).

Wheat is grown under a greater variety of climatic conditions than any other grain save barley. The distribution of

wheat over the world is especially wide as compared with corn (compare Chart 55 with Chart 48, p. 446).¹ A very pertinent factor accounting for the widespread production of wheat is that, although not so winter-hardy as rye, wheat considerably excels barley and oats in winter-hardiness, whereas corn cannot be grown in the winter at all except in or near the tropics. Wheat requires slightly more warmth than barley and oats, and its growing period is somewhat longer; wheat, therefore, does not extend so far north or so high into the mountains as barley and oats, but the significance of these limitations is not very large. The longer growing period of wheat, it is true, limits also the competition of wheat in regions with certain types of adverse weather at time of maturing—too dry, too hot, or too moist.

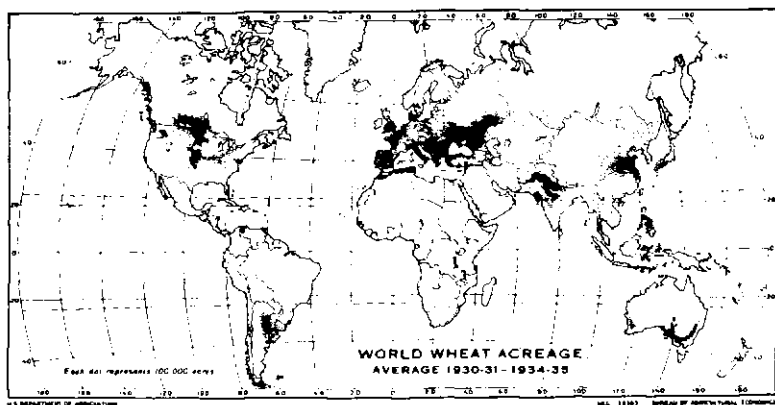
Contrary to a rather widely shared opinion,² wheat does not do particularly well under scarcity of moisture. Even if such definitely dry-weather crops as millets are disregarded, wheat is materially inferior to barley in ability to do with a small amount of moisture except where it can be grown as a winter crop while barley cannot survive the winter. As a spring crop wheat is affected by insufficiency of moisture even more than spring oats. Wheat withstands rather well a large amount of moisture, but the efficiency in utilizing moisture above the minimum declines rapidly. Corn is superior to wheat in this regard, while oats are harmed less than wheat by a near-saturation moisture content of the soil.

Wheat ranks last in yielding capacity, or shares this place with rye. The hard-spring-wheat belt of this country and Canada and the southwestern portion of the Russian spring-wheat belt—regions where spring wheat competes with winter

¹ Owing to the large number of acres per dot, Chart 62 (p. 524), showing the world production of barley, does not clearly demonstrate the fact that the production of barley is even more widespread than that of wheat. In comparing Charts 48, 55, and 62, moreover, it must be considered that data for China were not available in the years to which Chart 62 pertains.

² To quote E. A. Starch: "wheat is better adapted to an arid climate than any other cultivated crop . . ." *Journal of Farm Economics*, February 1939, XXI, 117.

CHART 55



rye, spring barley, and spring oats in drier climates—are among those where yields of wheat are poorest relative to those of the other small grains. Spring barley may outyield spring wheat under these conditions by as much as 40 per cent on soil ideal for wheat. The advantage in yield of fall-sown barley over fall-sown wheat in most regions with Mediterranean or similar climates, such as California, northern Africa, and India, is also large, in places as large as the advantage of spring barley over spring wheat in the drier regions mentioned above.

On the other hand, in areas where wheat is able to survive the winter while no winter barley or winter oats can be grown, wheat produced by intensive methods on soils adapted to it yields almost as much as, or even more than, any other small grain. This favorable showing is due to the combined effect of the higher yield of winter grain, the lesser inferiority in yield of wheat at a better supply of moisture, and the ability of winter wheat both to stand and to repay the most intensive methods of crop production. Most of northwestern and north central Europe is most important among such regions. Yields of winter wheat compare rather favorably with those of spring barley and spring oats also in those drier regions where the

summer heat considerably affects the yields of spring-sown small grains. The main regions of this type are the hard-winter-wheat region of this country and almost the whole portion of the Russian chernozem region that is adapted to winter wheat.

The low yielding capacity of wheat in general and specifically its inferiority in yield in drier regions, as well as its relatively small response to certain cultural practices, are largely explained by the greater proportion of straw to grain in wheat as compared with barley or oats. Only the rye plant produces proportionately more straw.

The ratios of the cost of producing wheat to those of the other small grains on the whole coincide fairly well with the ratios in yields, but the range is narrower. Where yields of coarse grains far exceed those of wheat, the cost of production of wheat may be somewhat less unfavorable to wheat than the ratio between yields. Where wheat outyields coarse grains under intensive methods of crop production, it is nevertheless the more expensive grain to produce, because the excess in yield does not suffice to offset the excess in the cost per acre. In these circumstances the difference in favor of coarse grains is usually small, it is true, and in any case it tends to be materially less than that observed in drier regions where spring wheat competes with spring barley, spring oats, and winter rye, and where fall-sown wheat competes with fall-sown barley (see Table 25, p. 411).

WORLD PRODUCTION

Wheat leads the other grains here studied in world production. About 38 per cent of the world acreage (ex-China) in the five grains was in wheat in 1932-36. In spite of the lower yielding capacity and large proportion of wheat acreage in regions with low average yields, the share of wheat in world production still amounted to one-third of the total in those years (Tables I and II).

The borderline between drier and moister regions is not

drawn distinctly (pp. 280-81); even if it were, it would involve an immense amount of work to determine exactly the distribution of grain acreages among different types of climate. Appraised rather roughly,³ the wheat acreage in drier regions, excluding irrigated wheat, is equivalent to approximately two-thirds of the world wheat acreage ex-China. Moreover, so far as the soil is not too light and the regions involved are located in the temperate zone, most of them are an almost undisputed domain of wheat.

WORLD PRODUCTION: INSUFFICIENT MOISTURE

Three groups of regions where wheat is grown with insufficient moisture must be distinguished. The largest is the one in which only rye can be grown as a winter crop; it includes almost half of the wheat acreage grown in drier climates without irrigation and almost one-third of the wheat acreage of the world ex-China. The second group, with about one-fifth of the world wheat acreage grown with insufficient moisture, is that in which both rye and winter wheat can be grown as winter crops while oats and barley do not survive the winter. The third group is composed of those drier regions where at least rye, wheat, and barley can be sown in the fall (or winter); it includes about one-third of the wheat acreage grown without sufficient moisture.

Wheat is the strongest competitor for acreage in those drier regions where fall-sown wheat can be grown while fall-sown barley and oats do not survive. Corn in sections relatively better supplied with moisture, and sorghum in dry and hot regions, are the only serious competitors of wheat. The position of wheat is very strong also in regions where spring wheat competes with spring barley, spring oats, and winter rye. Corn, where moisture is not too scarce and warmth is sufficient, as well as barley, are the strongest competitors. Wheat proves less invincible in those regions with insufficient moisture where

³Partly on the basis of data in M. K. Bennett and H. C. Farnsworth, "World Wheat Acreage, Yields, and Climates," *Wheat Studies*, March 1937, XIII, 279 ff.

fall-sown barley is grown along with fall-sown wheat; in some such regions barley even succeeds in relegating wheat to a secondary position. But usually no competition of corn is encountered, while competition of sorghum is merely local.

Winter wheat versus spring barley and spring oats.—The group of drier regions where winter wheat competes with spring oats and spring barley includes the hard-winter-wheat region of the United States, the drier section of the portion of the Russian chernozem region adapted to winter wheat (with an adjacent portion of Rumania), and a large portion of the Pacific Northwest wheat belt. Kansas (except its eastern portion) is the recognized center of the hard-winter-wheat belt of the United States. In addition, it includes Nebraska, the panhandles of Oklahoma and Texas, and the Mountain states except Idaho.

The feature of this type of wheat region is that competition of other small grains may be expected to be least, although it is not always least in fact. It is rather hot for spring barley and especially for spring oats, while winter rye does not present advantages on better soils. In sections relatively better supplied with moisture, corn and—in dry and hot sections—sorghum are the most serious competitors.

Chart 51 (p. 453) shows indeed that on the basis of average yields, costs, and prices there is little room in Kansas for any small grain other than wheat, even as a subsidiary crop, for their prices are far too low in relation to their costs. Rye could be grown as winter grain the same as wheat, but no substantial advantage would be gained by including it in the rotation. Barley and oats are grown as spring grains and, in the conditions of Kansas, permit a material improvement in the utilization of labor and capital; but the difference in returns is too large to justify a considerable proportion of acreage in these grains. Chart 52 (p. 454) shows that in southwestern Kansas, the driest portion of the state, the acreage in all grains other than wheat constitutes only a moderate fraction of the grain acreage. There, and still more on un-

irrigated lands farther west, continuous winter wheat or winter wheat alternated after one or more years with fallow proves the most profitable cropping system. Exhaustion of the soil is more likely to cause land to revert to permanent pasture than to enforce rotations in which winter wheat is reduced to only a moderate role. Sorghum is the only grain which seems to have a great chance to gain from a shift from exclusive wheat growing, though its usefulness is impaired by the unfavorable effect it has on yields of winter wheat following it in rotation.

Exclusive growing of winter wheat (with or without intermediate fallow) in the drier portions of the Russian chernozem region adapted to winter wheat (see Chart 22, p. 217) should be still more profitable than in the hard-winter-wheat region of the United States, because there the seasonal distribution of precipitation is somewhat more favorable for winter grain than in the hard-winter-wheat region. Yet exclusive growing of winter wheat is rare in Russia. In the Crimea, which probably has the largest proportion of acreage in winter wheat, this grain occupies slightly more than 50 per cent of the total grain acreage (official data of 1934). The great density of population gives rise to types of crop production hardly justified by the climate.⁴ Future changes in acreage in the Russian winter-wheat regions are likely to be at the expense of coarse grains, except perhaps corn and sorghum.

According to total amount of annual precipitation, the wheat belt of the Pacific Northwest (in Washington, Oregon, and Idaho) ranks with the drier regions, and some of it with their extreme parts. But the exceptional moisture-retaining capacity of the soil of this region imparts to it some of the properties of moister regions. In spite of the predominance of winter precipitation there, spring grains, even spring wheat, are far less discriminated against, as compared with winter

⁴How unprofitable relatively is the growing of grains other than wheat in Crimea (Crimean wheat in quality is the cream of the wheat of the world) can be imagined from the fact that, on the average in 1928-32, winter wheat yielded 770 kilograms per hectare while the yields of barley, oats, and corn were equivalent to 520, 540, and 470 kilograms, respectively. Winter wheat would have been considerably more profitable even if all of it were grown on fallowed land while all spring grains were grown on stubble.

grains, than in other regions with a similar seasonal distribution of precipitation. But the same exceptional soil structure makes alternate fallowing the most profitable form of crop growing, and alternate fallowing reduces to a minimum (particularly with the nonshattering types of wheat well adapted to that region) the advantage from growing on the same land some other small grain in rotation with wheat. Under moisture and temperature conditions of the region, corn also has no claim on the land.

The peculiarities of the soil of the Pacific Northwest grain belt contribute much toward explaining the virtual monopoly held by wheat in the whole region. Yet the competitive power possessed by wheat there seems to be even stronger than can be inferred from the exceptional water-holding capacity of the soil. There is something almost miraculous about it, as is true also of the high yield of spring wheat on irrigated land at Prosser in the same state of Washington to which most of the Pacific Northwest wheat belt belongs (see p. 332). Even the cereal hay, which is in wide use there, is almost exclusively wheat hay.⁵

Spring wheat versus spring barley, spring oats, and winter rye.—These conditions are found mainly in only two areas, but these are vastly important: the hard-spring-wheat region of the United States and Canada, and the Russian spring-wheat belt. Since only small portions of these regions are accessible to corn, the competition is primarily among small grains. Barley has the advantage of much higher yield in a large por-

⁵ The exceptionally favorable conditions for wheat production in the Pacific Northwest are plainly revealed in price ratios between wheat and other grains. Taking the farm price of wheat = 100, those of the other grains in Washington were:

Grain	1909-10 to 1913-14	1925-26 to 1929-30	1932-33 to 1936-37
Rye	106	91	103
Barley	92	79	91
Oats	106	90	103
Corn	110	102	113

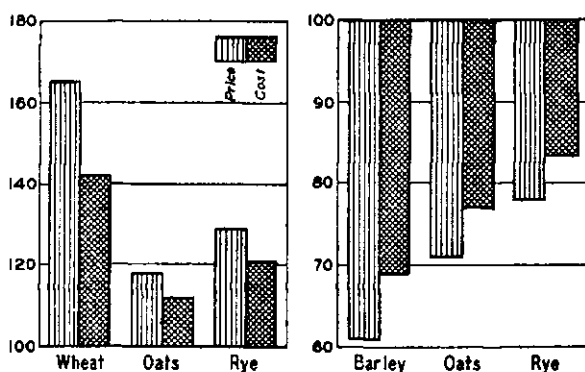
The price ratios can be so favorable for coarse grains in such a distant state as Washington only because natural conditions greatly favor wheat, and all grains other than wheat are therefore produced only in tiny quantities and fetch scarcity prices.

COMPETITION AMONG GRAINS

CHART 56.—RELATION BETWEEN PRICE RATIOS AND COST RATIOS OF SPECIFIED GRAINS, IN THE PRAIRIE PROVINCES OF CANADA*

(Price or cost of barley = 100)

(Price or cost of wheat = 100)



* Ratios between farm prices of 1925-26 to 1929-30, as officially computed. Ratios between the costs of production as computed from data for 1923 and 1924.

tion of the area, and rye that of being sown at a time different from the other grains.

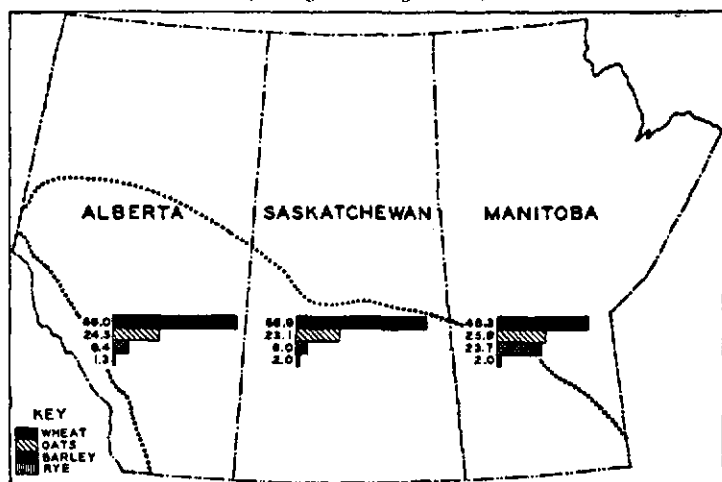
Chart 56 compares the ratios between the farm prices of different small grains in 1925-26 to 1929-30⁶ in the Canadian Prairie Provinces with the ratios between the costs of production of the same grains as computed at uniform rates for this region in chapter xvi, at the left in terms of barley, at the right in terms of wheat. In the years specified, oats were relatively more profitable to produce than barley. The situation, however, was reversed in 1932-33 to 1936-37, when barley, which is cheaper to produce than oats, was also higher in price than oats (Chart 2, p. 10). In 1925-26 to 1929-30 rye too was more profitable to produce than barley, but that period was one of abnormally high rye prices. In 1932-33 to 1936-37 rye had the lowest farm price while exceeding both barley and oats in cost of production.

Relative advantages in favor of oats, barley, or rye, small as they are, are to some extent reflected in the percentage distribution of the acreage shown in Chart 57. In the final analy-

⁶ A period rather typical for wheat, the principal grain of the region.

CHART 57.—PERCENTAGE DISTRIBUTION OF ACREAGE IN SPECIFIED GRAINS IN THE THREE PRAIRIE PROVINCES OF CANADA, AVERAGE 1935-37*

(Total grain acreage = 100)



* Official data. The dotted line indicates the approximate northern boundary of grain cultivation, here taken from map in Searle Grain Co., Ltd., circular of July 19, 1939.

sis, however, there is not much room for competition among those three grains, because the land is occupied anyway. The favorable relationship between the cost of production of wheat and its price—relative to those of the other grains—is the determining factor for the distribution of acreage in most of the Prairie Provinces. The exceptional position occupied by wheat becomes evident at a glance at the right-hand section of Chart 56 in which the data are presented with wheat as the base. All grains are a losing proposition as compared to wheat, and the differences between oats, barley, and rye are almost insignificant; one is slightly less unprofitable and the other a little more so.⁷

⁷One can be rather confident that the unprofitableness of coarse grains is not merely a relative one. If the officially computed costs of production are compared with the prices in the five years specified, wheat returned a profit of about \$2.00 per acre, oats and rye returned a profit of about \$1.00, and barley none. But a profit over the cost of production which includes charges for all items (save management, the cost of which, in our opinion, should not be considered in family farming at all) is unlikely in grain production even in such a relatively favorable period as that of 1925-26 to 1929-30. It

The advantage of wheat over coarse grains as revealed in Chart 56 is in general sufficient to insure wheat a predominant position in production. Some qualifications nevertheless are needed. The costs used in the comparison are costs at uniform rates; small acreages of coarse grains can be produced more cheaply. Since, however, the managerial and other advantages of replacing part of the wheat by other small grains are only slight to moderate under the specific conditions found in western Canada (see p. 353), the saving on costs of producing coarse grains grown subsidiary to wheat as compared to costs at uniform rates may be not quite sufficient to permit any of these other grains to attain an important position even in such a secondary role. But in substantial portions of the provinces coarse grains get further support from soil and/or weather.

In Manitoba the exhaustion of the soil,⁸ and especially its weediness, make conditions less favorable to wheat than in the other two provinces more recently taken into cultivation. The official data on the cost of production show indeed that the cost of wheat is relatively higher in Manitoba (pp. 393-94). The shorter distances to the markets for animal products also slightly strengthen the competition of coarse grains with wheat in this province. Furthermore, the "park lands" in the north of the whole grain belt are less adapted to wheat, while shortness of the frost-free period necessitates the grow-

seems reasonable to agree with M. K. Bennett ("Average Pre-War and Post-War Farm Costs of Wheat Production in the North American Spring-Wheat Belt," *Wheat Studies*, May 1925, I, 182-84) that the officially computed cost of production in the Prairie Provinces was underestimated (not all cost items were included; reporting farms were over-average in efficiency). Even the assumption that prices covered all costs of wheat production, including a full charge for land use, seems to be rather optimistic. Yet on this assumption, oats and rye produced at costs computed at uniform rates were able to return all expenses save land use, but only about two-thirds of the land charge. In the situation rather common for such regions as the provinces, that wheat even in time of prosperity does not quite return the full charge for land use, coarse grains cannot earn a remuneration for the land to speak of.

⁸ An agricultural survey of Manitoba undertaken by the Department of Agriculture of that province stated, "In a generation more than one quarter of the potential wealth of the surface soil has disappeared." Quoted by Sir Henry Rew, *Economic Resources of Canada* (Great Britain Ministry of Agriculture and Fisheries, Economic Series 3, 1925), p. 56.

ing of large quantities of the less desirable Garnet (a very early-maturing variety of wheat), and the quality of wheat is damaged by unfavorable autumn weather more frequently than farther south.⁹ Finally, even the soils of central and southern Saskatchewan and Alberta are not all equally well adapted to wheat.

But the larger the areas in which wheat makes a poorer showing than on the basis of the data for the provinces as a whole, the stronger is its position on unexhausted better soils. On these, coarse grains should not be on a competitive basis even at the lower costs for crops produced in small quantities.

Statistics of production and marketing clearly reveal that grains in the Prairie Provinces behave as they can be expected to behave according to the relationship between prices and costs. Wheat greatly predominates in production, still more in marketing. Relatively small amounts of other grains are produced either under protection of handling charges (mostly oats for horses), for combating weeds (mostly barley), or on lands less adapted or unadapted to wheat—either originally or worn out through cultivation (all coarse grains). Not less than 65 per cent of the total grain area of the Prairie Provinces was in wheat in 1935–37. The remainder was made up largely of oats. But oats are mainly raw material for producing wheat. The competition of tractors is not very strong in Canada, and horses are still widely used. Only the area in barley and rye can be considered as grain area none of which is devoted to wheat. Merely 9 per cent of the grain acreage was in barley in the same years, and only 2 per cent in rye.

Small as is the role of grains other than wheat in the Prairie Provinces, the picture of the provinces as a whole does not tell the full story. In Manitoba, the oldest of the three, with soil largely deprived of its virgin powers, wheat in 1935–37 occupied 48 per cent of the grain area, i.e., for each acre of wheat there was an acre in coarse grain. In Saskatchewan

⁹ See C. P. Wright and J. S. Davis, "Canada as a Producer and Exporter of Wheat," *Wheat Studies*, July 1925, I, 217–88, for detailed description of the wheat region of the Prairie Provinces.

and Alberta, on the other hand, the percentages were 69 and 66, respectively (Chart 57). Some 32 per cent of the barley acreage of Saskatchewan was found in 1936 in the two—out of a total of nine—northern crop-reporting districts less adapted to the production of the best wheat and having only 14 per cent of the provincial wheat acreage. The tendency of nonwheat grains to concentrate on poorer soils is particularly noticeable with regard to rye, because barley needs rather good soil and is grown primarily to combat weeds on such soils, while oats are largely grown where the horses are that help grow the wheat. In Saskatchewan in 1936, the total acreage of winter rye constituted only 1.2 per cent of the grain acreage, but in the southwestern crop district the percentage was 6.7; and 77 per cent of the area in winter rye was concentrated in three crop-reporting districts that had only 38 per cent of the wheat acreage of the province.

Since coarse grains are needed on farms for feeding the large number of horses and the moderate number of productive livestock, wheat dominates marketing even more than it dominates production. Out of an oats crop of 70.2 million centals harvested in the Prairie Provinces on the average in 1930-31 to 1934-35, only 10.9 million centals (15.5 per cent of the crop) were inspected in the "Western Division."¹⁰ In addition, 7 million centals of barley (23 per cent of the crop) and 0.5 million centals of rye (11 per cent of the crop) were inspected. These figures compare poorly with the 160 million centals of wheat inspected in the same years (81 per cent of the crop). In 1928-29, the year of the largest shipments of coarse grains from Saskatchewan in a decade, these amounted to only 13 per cent of the shipments of wheat on the basis of weight and to less than 10 per cent on the basis of value.

In southeastern North Dakota, wheat encounters a strong competitor in corn; most of this corn is not harvested for

¹⁰ Inspections and shipments coincide rather closely with marketings in western Canada.

grain, it is true (p. 452). To have a small proportion of the acreage in such corn proves profitable, indeed, almost throughout the state. So far as the competition of wheat with other small grains is concerned, however, the situation in North Dakota, the center of the hard-spring-wheat region of the United States (with northwestern Minnesota, western and central South Dakota, and most of Montana making up the rest) is rather similar to that in the Prairie Provinces. The competitive position of wheat relative to coarse small grains in the hard-spring-wheat region of this country is likely to be even stronger than beyond the international line, even if our computation is in error—as we believe it is—in showing that the cost of production of oats and barley in North Dakota is less favorable, relative to that of wheat, than in the Prairie Provinces. In this country, the prices of hard spring wheat, grown on both sides of the international line, tend to be at a large premium, while prices of coarse grains are depressed by competition of the cheaply produced corn.

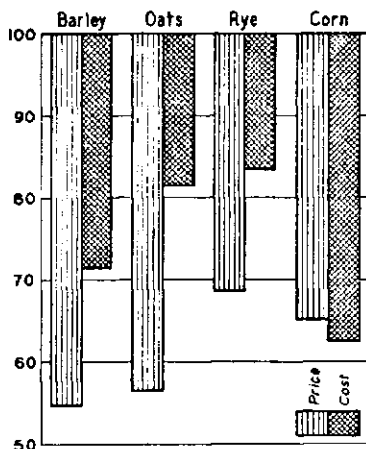
According to Chart 58, the relation between prices and costs in North Dakota in 1922–31 was least favorable for oats, while for rye it was more favorable than for either oats or barley. But prices in 1932–36 made rye the most unprofitable crop. Again it is the relation between the price and cost of wheat that deserves to be emphasized most. If the data in Chart 58 are reworked to the barley base, the price ratio for wheat exceeds the cost ratio by 30 per cent in North Dakota, while in the Prairie Provinces the advantage of wheat is equivalent to only 17 per cent.¹¹

Data in Chart 59 indicate that the proportion of wheat acreage to total grain acreage in the western two-thirds of North Dakota is approximately the same as in Saskatchewan (Chart 57, p. 479) with which that portion is similar in climate. Since the soil in North Dakota is more nearly exhausted than that of Saskatchewan and since, moreover, poorer soil has been

¹¹ The more favorable showing of wheat in North Dakota is caused partly by the use of prices for different periods, but wheat in North Dakota has a material additional price advantage even if the same period is used.

CHART 58.—RELATION BETWEEN PRICE RATIOS AND COST RATIOS OF SPECIFIED GRAINS, IN NORTH DAKOTA*

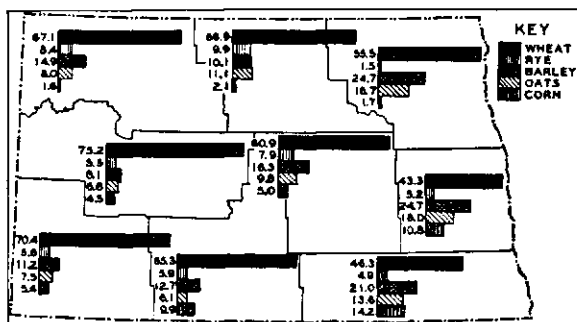
(Price or cost of wheat = 100)



* Ratios between farm prices in 1922-31. Ratios between the costs of production in 1922-31 as shown in Table 25, p. 411. The ratios between the cost of production of corn and small grains are valid, if at all, only for southeastern North Dakota.

CHART 59.—PERCENTAGE DISTRIBUTION OF ACREAGE IN SPECIFIED GRAINS IN CROP-REPORTING DISTRICTS OF NORTH DAKOTA, 1929*

(Total grain acreage = 100)



* Official data. For small grains, acreage harvested for grain; for corn, total acreage.

taken into cultivation there more extensively than north of the border, the distribution of the acreage in the indicated portion of North Dakota can be accepted as supporting the conclusions drawn from the comparisons of the cost and price

data—that on equal soils it is relatively more profitable to grow wheat in North Dakota than in Saskatchewan. North-eastern North Dakota, which in climate resembles Manitoba, has a larger proportion of the acreage in wheat than the Canadian province just beyond the border. As shown by data on the typical farming systems in different type-of-farming areas of North Dakota,¹² outside of the areas suitable for corn, the practice is widespread of having nearly two-thirds of the crop area (except the area in wild hay) in wheat. This practice involves growing wheat after wheat on the same land every third year.

The situation in the spring-wheat region of Russia, the largest stretch of land in the world producing a distinct type of wheat (in Chart 22, p. 217, only the portion of the spring-wheat area located in European Russia can be seen), is similar to that of the hard-spring-wheat region of North America. It is true that slight modifications are introduced by the low standard of living—producers there must be satisfied with the kind of bread grain that their soil can produce, and this accounts partly for the larger acreage in rye—and by the fact that oats rather than barley are the grain most cheaply produced. The situation in that part of Russia can be demonstrated by the distribution of the acreage in West Siberia (data of 1934):

Grain	Thousand hectares	Percentage of total
Winter wheat	3	0.0
Spring wheat	4,942	61.7
Winter rye	634	7.9
Spring barley	129	1.6
Spring oats	1,854	23.2
Buckwheat	113	1.4
Millet	338	4.2
Corn	none	0.0
Total (excluding spring rye for lack of data)	8,013	100.0

¹² F. F. Elliott and others, *Types of Farming in North Dakota* (U.S. Dept. Agr. Tech. Bull. 102, December 1928), p. 15.

The area in wheat was equivalent to approximately 60 per cent of the total grain area, although this comprises substantial stretches of poor soils.

Fall-sown wheat versus fall-sown barley and fall-sown oats.—The third group of wheat regions with insufficient moisture includes a good many countries and regions. These comprise California; northeastern Africa; most of Spain; parts of Italy, Turkey, and other Mediterranean countries; Persia; Turkestan, Russia; parts of British India; and the grain belts of Australia and western Argentina. Even more than in the second group, competition is reduced to that between the small grains. Moreover, rye definitely drops out of the picture, because there it not only does not possess the advantage of being the only grain sown in the fall, but also suffers from the heat. Secondly, with moisture scanty, fall-sown oats compare much less favorably in yield with fall-sown wheat and fall-sown barley than where all three grains are sown in the spring. This is particularly true of regions with a typical Mediterranean climate. Thus wheat in general has to face the competition only of barley. But the wheats produced in those regions are less valued than those of the hard-winter-wheat and hard-spring-wheat regions, while their barleys, in part at least, are of more desirable quality. In northeastern Africa and Asia further divergences are caused by the fact that barley is largely used for food by the poor populations inhabiting them.

The cost of production of barley in California, as computed in chapter xvi (p. 396) at about 25 per cent less than that of wheat, is one of the most unfavorable for wheat.¹³ At such cost ratios wheat needs the support both of high marketing costs and of the quality factor in order to excel in competition for acreage. But in California the quality factor is against wheat, while the effect of the fact that California is on an import basis in wheat used for breadmaking is offset by the fact that it is on an import basis also in feed grain. While in North Dakota barley tended to cost only about 60 per cent of

¹³ This cost ratio is for grains in sacks; with the costs of sacks eliminated, the ratio is the same as that computed for the Prairie Provinces.

the price of wheat, its price in California was equivalent to 88, 70, and 75 per cent of the wheat price (farm prices in all cases) in the three 5-year periods covered in Charts 2 to 4 (pp. 10-12). Moreover, this level of barley prices reflects its great strength as a competitor for acreage. Nearly 50 per cent more land is in barley than in wheat in California, with all other grains in minor roles.¹⁴ The large proportion of barley in the total supply of feed grain inevitably results in a depressed price level of this grain. With natural conditions less favorable to barley, its price would undoubtedly be substantially higher relative to those of wheat and the other grains.

Much of Spain has a climate very similar to that of California, and we find there about the same price ratio between wheat and barley (Charts 3 and 4, pp. 11 and 12); yet in Spain wheat predominates (Chart 61, p. 494), with barley, it is true, a strong second in regions with the least amounts of precipitation. The facts that Spaniards are satisfied with the quality of their wheat and much wheat indeed is consumed locally, and that precipitation is somewhat more plentiful in the grain-growing sections of Spain than in those of California, may help to explain the difference between the two regions.

French northern Africa resembles California in climate even more than Spain does. But economically French northern Africa and California differ even more than Spain and California. The poor population has to use for bread the grain which yields the greatest poundage, i.e., barley. Want further necessitates cultivation of dry lands such as are used in California only as pasture or not at all. French northern Africa, in fact, is among the few countries where grain grow-

¹⁴ On the average in 1933-37 the acreage in California was as follows:

Grain	Thousand acres	Percentage of total
Barley	1,079	50.3
Wheat	747	34.8
Oats	129	6.0
Rye	8	0.4
Corn	64	3.0
Grain sorghum ...	117	5.5
Total	2,144	100.0

ing extends almost up to the desert. Barley again is the gainer. The primitive character of cultural practices is another stimulus to barley production. As a result, we find large barley acreages in all three French protectorates,¹⁵ although the prevailing price ratios to wheat¹⁶ would exclude barley in any country with a somewhat better standard of living and more up-to-date cultural practices. In Morocco barley dominates, while in Tunis and Algeria it is a strong second to wheat. The domination of wheat is limited to the better watered sections. Deeper into the interior much more barley than wheat is grown in every protectorate, as demonstrated by the situation in Tunis in Chart 42 (p. 298).

Most of the barley in the protectorates is consumed by the natives who grow it, but substantial amounts are produced also for the market. Because of extreme year-to-year variations in yields, growers have to produce relatively large surpluses in fat years to assure themselves the food for lean years. Moreover, the extremely unfavorable price level for barley (and other coarse grains) has prevailed only since the beginning of the recent depression, and has already caused some shift in acreage.¹⁷ The smallness of the shift may be explained by the backward population and by the large proportion of barley which does not enter the market.

¹⁵ The grain acreages harvested in 1937 are as follows, in thousand hectares:

Grain	Tunis	Algeria	Morocco
Wheat	983	1,745	1,225
Barley	620	1,252	1,941
Oats	37	193	42
Corn	} 27	6	453
Grain sorghum		10	128
Millet .....	..	1	21
Rye .....	..	1	4

¹⁶ On the average in 1931-35 the price of barley was only 46 per cent of that of durum wheat and 39 per cent of that of common wheat in Tunis (*Annuaire statistique de la France* in different years).

¹⁷ In Algeria the acreage in wheat expanded from 1,536,000 hectares in 1929 to 1,745,000 in 1937, while the barley acreage declined from 1,431,000 to 1,252,000 hectares. In Tunis the wheat acreage merely increased from 701,000 to 983,000 hectares, a larger increase than that of barley (from 505,000 to 620,000 hectares). But in French Morocco the acreage in wheat remained unchanged in the years specified, while barley showed an almost unbelievable jump from 1,311,000 to 1,941,000 hectares; the use of data for periods rather than for individual years indicates an increase in acreage of both grains, but the increase in barley was much the larger.

The Mediterranean climate extends well into Asia, and everywhere we find the same picture: wheat the dominant crop, barley the more powerful competitor (1) the drier the climate and poorer the soil, (2) the poorer and more backward the population, and (3) the more isolated the particular locality from the market.¹⁸

The situation in California, and in Spain and other countries around the Mediterranean, presents an illuminating picture of quite different results for the competition between wheat and barley in the same climatic but divergent economic conditions. Californians not only insist on wheat bread but can afford to bring wheat better than their own from distant producing regions; their own grain land is therefore mainly in barley. The Spaniards and some other people in the Mediterranean can afford wheat but have to be satisfied with the type of wheat their soil can produce; the wheat acreage in Spain is more than twice that in barley. Finally we have such poor populations as those of French northern Africa most of whom can afford only barley, and to barley their soil is therefore more largely devoted. A similar graduation could be easily presented for the competition between wheat and rye.

Western Australia and a portion of South Australia have the Mediterranean climate, while the climate of the remaining portions of the Australian grain belt is rather similar. Yet the competitive positions of different grains differ greatly from those observed in other regions with Mediterranean climate. Attempts to explain this difference have been made on pages 299-300. Wheat strongly predominates in Australian grain production, while barley has as yet proved unable to secure a modest place even as a secondary crop. So far as wheat cedes territory, it is to oats.¹⁹ Yet oats command as high a price

¹⁸ For the situation in Turkey see G. Stratil-Sauer, "Cereal Production in Turkey," *Economic Geography*, October 1933, IX, 328.

¹⁹ Of the 14,427,000 acres harvested for grain in Australia in 1935-36, 11,957,000 were in wheat, 1,564,000 in oats, 486,000 in malting barley, 79,000 in other barley, and 8,000 in rye. But of the grain acreage harvested for hay, 1,913,000 acres were in oats and only 731,000 acres in wheat. For every acre in nonwheat harvested for grain and hay there were slightly more than three acres of wheat.

as wheat (see prices in Melbourne in Chart 2, p. 10). These facts should indicate that wheat is at a lesser disadvantage with regard to yield in the Australian grain belts than it is in regions discussed earlier in this subsection. In the specific conditions of Australia (abundance of pastures, grain production mainly for export to distant markets) wheat would not be greatly endangered in its dominating position, even if a coarse grain could boast a yield as favorable in comparison with that of wheat as the barley yield in California.

Argentina is the only country in this group where wheat encounters the competition of corn, and this competition is moreover the only serious one. It is strong not only in the moister regions but also in the better watered portions of the drier regions (see pp. 455-56). The Argentine acreage in small grains other than wheat in general is limited either to poorer soils or to such acreages as are grown mainly for pastures. Some of these acreages are destined not for regular use but as a protection against a poor condition of regular pasture. This peculiar role of coarse small grains in Argentina is clearly evident from the consistently large proportion of acreages seeded but not harvested and from the large year-to-year variations in nonharvested acreages.²⁰ The *harvested* acreages of all coarse small grains constitute only a small percentage of the wheat acreage.²¹ As in Australia, oats rather than barley is much more widely grown in Argentina except on good soils in the southeastern portion of the grain belt.

²⁰ In the ten years ending with 1933-34, the harvested acreages of oats, barley, and rye were, in percentage of acreage sown:

Year	Oats	Barley	Rye
1924-25	65	49	42
1925-26	70	80	71
1926-27	70	83	90
1927-28	55	66	76
1928-29	60	68	68
1929-30	58	55	42
1930-31	57	56	38
1931-32	59	70	70
1932-33	60	83	73
1933-34	46	77	41

²¹ In 1933-37, harvested acreages of oats, barley, and rye, respectively, averaged 714, 539, and 307 thousand hectares; wheat, 6,313 thousand.

In British India, which has the monsoon type of precipitation, fall-sown barley again is the principal competitor of fall-sown wheat. But its position is not as strong as in countries with the typical Mediterranean climate. Much barley, in fact, is grown primarily in very dry and elevated areas. In the Punjab, the principal wheat province of British India, the price ratio of barley to wheat is about the same as in California, according to Charts 2 and 4. Yet the nonirrigated area in wheat in that province is about ten times as large as that of barley.²² Since the difference in yields between barley and wheat is probably less than, for example, in French northern Africa, there is also less inducement for the farmers to grow barley rather than wheat for their own use as food.

WORLD PRODUCTION: SUFFICIENT MOISTURE

About one-third of the world wheat acreage (ex-China) is grown with sufficient moisture, i.e., in moister regions or under irrigation. Approximately three-quarters of this area is grown with natural precipitation, about one-quarter is irrigated. Two major types of wheat growing with sufficient natural moisture must be distinguished: areas with temperatures adapted to corn, and areas unadapted to it. The bulk of the acreage of the latter type is located in western and central Europe, and is mostly grown under intensive to very intensive methods.

The competitive position of wheat in moister areas with temperatures adapted to corn was discussed in chapter xviii. It was found that in regions with temperature conditions well suited to corn, wheat generally proves inferior to corn in competitive power. Where corn can be grown as practically the only grain crop without sensible effect on yield, as in the sections of Argentina with a large alfalfa acreage, wheat gives way almost entirely to corn. The situation is similar for wheat where, as in the heart of the Corn Belt, rotational corn is much

²² The nonirrigated area in wheat in all of British India is about 3.5 times as large as the nonirrigated acreage in barley.

more profitable than continuous corn, but winter wheat does not fit well into rotation with it. On the other hand, where a small grain is needed to follow corn and winter wheat is appropriate for this purpose, as in a predominant portion of the Danubian region, the combination corn-winter wheat (the combination of the highest-yielding with the highest-priced grain) is so strong that almost no room is left for any other grain. This combination seems also to play a considerable and probably an increasing role in Argentina, and is widely used even where it causes more or less substantial inconvenience, as in the east, south, and southwest of the heart of the North American Corn Belt.

As previously, German conditions are used to characterize the situation in regions not adapted to corn. The conclusions with regard to the relative production costs in Germany are based on data for a limited number of farms (pp. 362-65). Yet the data seem to reveal a surprisingly precise picture when they are compared with the price ratios (Chart 60) and the result of this comparison is again compared with the distribution of acreages. The less favorable price ratios for wheat in Germany, as compared with those found in most surplus countries, are associated with a cost situation more favorable for wheat. The improvement in the relative cost, it is true, is not nearly so large as the decline in relative price. Still, on the basis of the data, no grain is more profitable to produce than winter wheat on better types of soil. In Germany, a price advantage of approximately

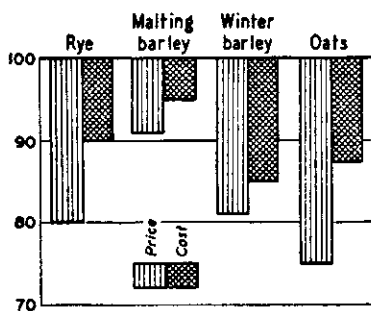


CHART 60.—RELATION BETWEEN PRICE RATIOS AND COST RATIOS OF SPECIFIED GRAINS ON GOOD SOILS, IN CENTRAL GERMANY*

(Price or cost of wheat = 100)

* Ratios between prices of 1932-33 to 1936-37 as in Chart 3, p. 11. Ratios between costs of production as computed from data of 1924-25 through 1928-29.

^a Based on the cost of production of spring barley as computed in chapter xvi, pp. 400-02.

20-25 per cent in favor of wheat suffices to insure that each piece of land intended for grain and even moderately adapted to wheat is used for it to whatever extent is consistent with the requirements of proper rotation. In postwar years wheat prices seldom exceeded the prices of other grains by more than the margin indicated; yet wheat was the only grain except winter barley the acreage in which could show an expansion.²³ It is hardly realized that, with the same price situation, barley would be the dominant crop in the Prairie Provinces of Canada, instead of occupying an acreage equivalent only to some 15 per cent of the wheat acreage.

Having got an idea of the cost situation in Germany, and having sharpened our eye by the preceding analysis, the attempt can be made to arrive at some conclusions regarding the competitive position of wheat in other deficit countries of western Europe simply by comparing the price ratios with the distribution of the acreages. Such a comparison is made for a few selected countries in Chart 61. Among them Italy displays the most favorable price situation for wheat; coarse grains there cost about two-thirds as much as wheat. This price encouragement has sufficed to give wheat possession of almost all the grain acreage except that in corn. Although the fulfillment of rotational requirements is very important where intensive methods of crop production are followed, they are obviously largely neglected in Italy. The wheat acreage constitutes almost 50 per cent of the total cropped acreage, which includes a large acreage in grasses two years old and over.²⁴ Spain, also represented in Chart 61, belongs with the drier regions and was therefore discussed earlier.

In France wheat on the average occupies half of the grain acreage—an enormous percentage for a country practicing intensive methods of crop production and having wide stretches of land little adapted or entirely unadapted to wheat. Only

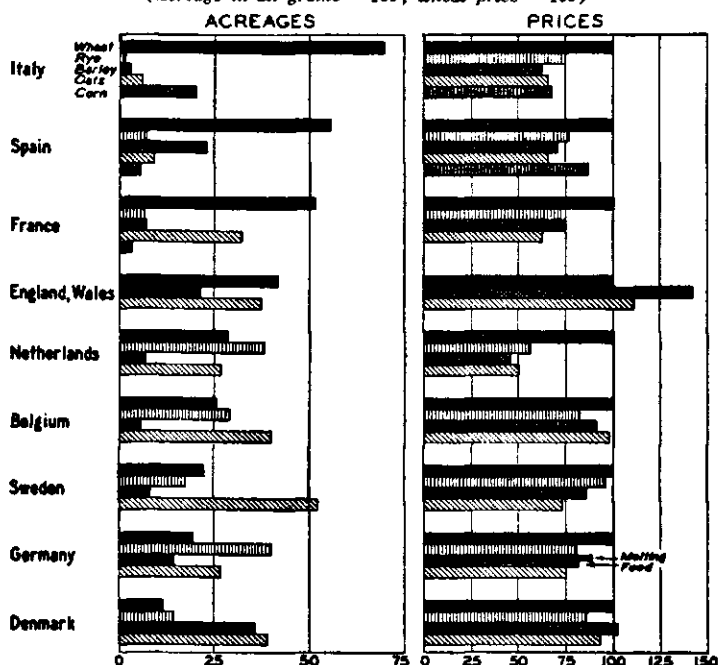
²³ The increase of the acreage in winter barley was even much larger than that of wheat, but for this there were specific reasons (see pp. 526-27).

²⁴ Grasses occupying the land more than one year are counted each year in full as cropped acreage.

COMPETITION AMONG GRAINS

CHART 61.—RELATIVE ACREAGES AND PRICES OF SMALL GRAINS IN SELECTED WEST EUROPEAN COUNTRIES*

(Acreage in all grains = 100; wheat price = 100)



* Acreages are for England and Wales, but prices are for Great Britain. Data on prices are from Chart 3, p. 11, for the years 1932-36. Data on acreages are from Chart 53, p. 459.

oats have been able to remain very important there, in spite of a rather low relative price equivalent to 60 or 65 per cent of that of wheat. The absence of heat, the relatively high yields of oats in moist climates,²⁵ and their good fit into rotation with the price-favored wheat, may be the major reasons.

Farther north and east in countries where grains have long remained unprotected by tariffs and the price ratios have been much less satisfactory for wheat than in protectionist southwestern Europe, wheat is produced in much smaller quantities, especially as oats steadily gain in competitive power to

²⁵ Oats are grown primarily in northeastern France; see L. G. Michael, *Agricultural Survey of Europe: France* (U.S. Dept. Agr. Tech. Bull. 37, February 1928), p. 80, Fig. 10.

the northward, owing both to cooler climate and higher humidity, while eastward the soil increasingly becomes an impediment to wheat growing. Still, as much as 30 per cent of the Belgian grain area is in wheat, although only rye tends to be cheaper than wheat by more than 10 per cent. In England and Wales the proportion of the grain acreage in wheat is even larger. In both countries wheat is likely to occupy most of the better land intended for grain except for some land especially adapted for malting barley (this too is land less suitable for wheat), but the price-cost ratios hardly justify sacrificing rotational requirements in order to grow more wheat. In the extreme humidity of Scotland and Eire, wheat definitely has to give way to oats, owing to the relatively advantageous position of the latter with regard to both yield and quality. The situation in large portions of Sweden is similar to that in Scotland and Eire. The proportion of the grain acreage in wheat also declines rapidly east of Belgium, primarily owing to the lesser proportion of land adapted to wheat.²⁶ Rye becomes increasingly important.²⁷

On irrigated land, wheat occupies a dominant position among the grains studied, although the poorer quality of irrigated wheat is a handicap. The ample supply of water reduces the advantage of barley in yields, while the usually very dry air of the irrigated areas is conducive neither to corn nor to oats. The higher price of wheat is another and probably the most pertinent factor responsible for the domination of wheat on irrigated lands, because irrigation on a large scale is practiced primarily in distant countries where the margin between the prices of wheat and coarse grains tends to be wide. Even with a slightly smaller response to irrigation, wheat would usually be more able to repay irrigation costs than the other grains here studied.

About 75 per cent of the irrigated area in wheat, barley,

²⁶ The acreage in wheat in the Netherlands was only about 13 per cent of the total grain acreage, before the inauguration of the protectionist policy in the recent depression.

²⁷ The competition of wheat with rye in this region is discussed in some detail in chapter xx.

and corn in British India is devoted to wheat. In Spain wheat occupies more than half of the irrigated area in all grains. In the United States, 40 per cent of the irrigated land devoted to grains other than rice was in wheat in 1929, and no other grain had as much. More wheat than barley is irrigated in California, though the total area in barley is the larger. But corn proves stronger than wheat as a competitor for the irrigated land of Egypt.²⁸ In 1937, 1,463,000 acres were in wheat there as against 1,619,000 acres of corn and but 272,000 acres of barley.

WORLD PRODUCTION IN THE PAST

The dominant position of wheat in world production is of relatively recent date. Most of the present important producing regions did not exist at the turn of the nineteenth century, and wheat was also relatively much less important in many older producing areas. Rye then held a vastly stronger position, and even such grains as millet and buckwheat were much more important. The increase of world wheat production during the nineteenth century must have been greatly in excess of that of any other grain except perhaps corn.

This development was not maintained in about 30 years ending before the World War, for which some summarized statistical data are available;²⁹ the increase in wheat production in countries covered by those statistics was slightly less than that of corn, oats, and barley, and materially exceeded only the increase in the production of rye.³⁰ From the beginning of the World War, however, wheat production alone was able to show a material further advance (by about 30 per cent

²⁸ In Egypt, corn is grown not in the summer, as is usual in countries with moderate climates, but in the fall when the air is cooler and somewhat less dry.

²⁹ *Das Getreide im Weltverkehr* (already cited) provided a valuable computation of "world" production and "world" trade from 1878 to 1907. World production covers only Europe and the most important overseas countries. The writer has brought those data to the beginning of the World War in the *Encyclopedia of Soviet Exports* [translated title] (2d ed., Berlin, 1928), I, 178.

³⁰ According to data of the sources cited, wheat production increased by 82 per cent from 1878-82 to 1909-13 as against 87 per cent for barley, 103 per cent for oats, 89 per cent for corn, and 52 per cent for rye.

according to the computations of the International Institute of Agriculture), while the production of the other grains increased slightly or remained at the level of the last prewar years. In the whole period of 55-60 years for which data are available, the increase in "world" production was largest for wheat. Most significant of course is the gain of wheat over rye, its principal competitor in bread consumption. While in 1878-82 the accounted-for world production of rye was more than half that of wheat, now production of rye ex-China is equivalent to only about one-third of world wheat production.

This is not the place to attempt to answer the question whether supply or demand was the moving force in the rapid extension of wheat production. There is no doubt that growing supplies met with adequate increase in demand. Temporary overproduction cannot change this long-run trend. It is also irrelevant that recently the use of wheat for feed has increased materially, for this is still very small in comparison to total production.

The old and new regions.—The development in the past century was characterized by a struggle between old and new producing regions for a share in world wheat production. The outcome was a defeat of the old regions. But they were not content to acknowledge it, and fought back by both protectionist and constructive measures. Even most of those countries which did not resort to extreme protectionist measures succeeded in retaining for wheat a considerable share in their agricultural production.

The formerly unpopulated drier regions in North America, European Russia and Siberia, Argentina, and Australia were the principal, for some time practically the exclusive, source of the additional supplies of wheat. Wheat production in the older regions before the steam era was based on ratios of wheat prices to those of the other grains and other crops which could not be maintained after the new countries producing primarily wheat became an important market factor. Where such wheat production was not hastily protected by

tariffs, adjustment to new conditions could not be attained without considerable contraction of acreage and even production. But the adjustment was not restricted to such changes in production. The competition of the new regions was also met in the old regions by improvements in production technique, which not only reduced the cost of production of all grains but also brought about a reduction of the cost of production of wheat relative to those of the other grains.

The rate of development of means of transportation and farm machinery which permitted the agricultural penetration of new regions slowed down temporarily after the 'seventies or 'eighties of the last century. It is not improbable that during the 25 to 30 years preceding the World War the old regions regained a small part of their competitive power previously lost. This may be particularly true of the second half of the period, when extension of the crop acreage in new countries was increasingly to more distant or otherwise less favored sections.

In postwar years the competitive power of the drier regions received a new and very strong impetus from the mechanization of farm power for field work and from the invasion of the combine, the use of which before the World War was limited to Australia and the Pacific Coast of the United States. Wheat of the drier regions gained new strength. Not all the advantages from the new development in agricultural machinery have yet been realized. But sooner or later this new source of competitive power will have exhausted its effect. Moister regions have so far reaped less advantage from tractors and little from combines. But the suddenly enhanced competitive strength of drier regions was met by such a barrage of super-protectionism in deficit countries that the long-time trend toward an ever increasing share of the drier regions in world wheat production was reversed. Simultaneously moister regions continued their struggle for cheaper production. The use of commercial fertilizer, confined to the moister and especially to the deficit regions, has made surprising gains since the World War, chiefly through synthetic nitrogen.

Moreover, the competition of wheat from new regions and from old regions respectively differ greatly in character. The main weapon of old regions is the uninterrupted increase of the productivity of the soil. Grain production in the new regions, however, is properly described as mining. Some lands, it is true, can be mined for several hundred or even several thousand years, but the resources of some others are exhausted after a few decades. The famous "dry farming" technique is nothing but an efficient method of mining; this is especially true of fallowing. Stretches of new land—modest as yet, it is true—have already been exhausted and have had to be turned back into pasture. On large stretches of other land exclusive wheat growing has had to be replaced by rotations. While new land has been broken, land broken earlier has been producing less and less wheat. In this difference in methods of production the old regions may see some hope for the future, though probably a rather distant future.

WORLD TRADE

Although wheat did not occupy a conspicuous place in grain production before the steam era, it was the only grain of which large quantities could overcome the obstacle of the then prevailing high marketing costs. But the volume of the international wheat trade at that time can be considered substantial only in a relative sense, if in any.³¹

Steam transportation brought about a phenomenal increase in world trade in wheat. It opened up international trade for the cheaper grains also. On a percentage basis, coarse grains even showed much larger achievements than wheat, yet this grain remained the dominating factor. In the five years centered around 1880, imports of wheat (including flour) into

³¹ Unfortunately no summarized data are available for the period before 1878, but Great Britain was undoubtedly the only important deficit country in the pre-steam era. On the average in 1790-99 its net imports of wheat and wheat flour amounted to only 2.6 million bushels; a similar figure for 1830-39 when steam transportation had already started was 6.9 million bushels. Data on British imports and exports annually 1697-1842 are given in the official *Accounts and Papers*, 1843, LIII, 58. The data are probably slight underestimates, since wheat flour seems not to have been converted into wheat. See also *Wheat Studies*, July 1933, IX, 307, 310, which includes a chart covering British net imports of wheat and flour annually from 1815 to 1931-32.

most important European countries were about 50 per cent larger than the combined imports of the four other grains here studied. Up to the recent depression, international trade in wheat succeeded in holding that position. Only the unprecedented protectionist methods since resorted to in most deficit countries, which moreover in many countries have been applied with particular generosity to wheat, have caused a material loss in the relative position of wheat in the international grain trade. Yet world trade in wheat is still slightly in excess of that of the other four grains combined.

Chart 54 (p. 465) shows the distribution of wheat exports by countries. Unlike corn exports, which originate primarily in regions well provided with moisture, wheat is supplied by the drier regions. The same is true of exports of all other small grains, save for some rye originating in north central Europe and other minor exceptions. The insufficient ability of small grains to utilize large supplies of moisture is clearly reflected in this fact, although the large animal populations of moister regions are likely also to be a factor.

Data on distribution of wheat exports by countries for a long period show not only that practically all exports originate in new regions, but also that once-new countries have been again and again replaced by even newer ones. Russia and the United States, the two countries which supplied the bulk of wheat exports at the turn of the present century, are almost minor exporters now. Densely populated British India has almost disappeared as an exporter. The Prairie Provinces of Canada and Australia, whose rise is almost wholly a matter of the present century, together with Argentina which entered the world market only a little earlier, dominate the world markets. Thus deficit countries have been supplied with wheat mainly from the most freshly opened "mines." They might have run into difficulties, if trends in population growth as well as in diet had not changed more or less suddenly.⁸²

⁸² For some details on past developments in world wheat exports see the following issues of *Wheat Studies*: July 1925, I, 239, 261, 277, 284-85 (Canada); July 1927, III,

OUTLOOK

There remains substantial room for further replacement of other cereals by wheat, even if it be assumed that the rice world is barred to wheat bread forever. But much in this line has already been accomplished. Moreover, in the long run, population growth is the principal factor responsible for increases in the demand for agricultural and many other goods, and population growth has slackened greatly in recent years and threatens to be converted into a declining movement. These changes in population trends are the more significant, since per capita consumption of cereals displays a tendency to go down, and one can confidently point to no country where this development shows signs of having reached bottom. An increased proportion of wheat in total food consumption of cereals may maintain or even enlarge total wheat consumption, but anything approaching the spectacular rate of increase in the total demand for wheat as food in the past century is out of the question. Even for a moderate rate of increase, more cheerful prospects with respect to advances in the standard of living in countries with low standard are needful.

Past developments indicate that preference for bread made of strong wheat may make further progress, provided standards of living continue to rise. But the present outlook is gloomy for such an increase, and diets change rapidly.

Wheat has little chance to become an important feed grain. For this, the prices of wheat would have to be permanently at about the level of other feed grains, and the relative costs of production make such a development very unlikely. A substantial increase in the amounts of poor wheat used for feed, however, seems probable.

363, 405 (India); March 1930, VI, 280-82 (Danube countries); March-April 1932, VIII, 359, 375 (Russia); June-July 1934, X, 348 (net exports, 1885-86 to 1899-1900); November 1930, VII, 78-79 (net exports, 1900-01 to 1913-14, and 1921-22 to 1929-30); June-July 1934, X, 349 (international shipments, 1888-89 to 1900-01). In addition, each annual "Review of the Crop Year" gives charts and appendix tables on net exports and international shipments annually by countries, in the aggregate covering postwar crop years beginning with 1919-20, and charts of total international shipments annually from 1900-01, to Europe and to ex-Europe.

The future of world wheat production is nebulous. One can be fairly certain that wheat production will retain in full its share in total world production of the grains studied; the probable decline in the proportion of the bread grains in this total is likely to be entirely at the expense of rye. But what will be the rate of increase in world wheat production, and how will this increase be distributed between drier surplus and moister deficit countries? No definite answer to these questions and several others seems possible.

With the incessant sharpening of the weapons of modern technique, the extension of the land adapted to wheat production in moister regions may be pushed at an ever increasing rate. These regions have also the possibility of further substantial increases in per-acre yield. By preserving the present exorbitant protection of wheat, depriving their inhabitants of the opportunity to eat bread from imported strong wheat (which they mostly prefer), and preventing rapid growth of the demand for animal products which might divert acreage from wheat to feed crops, moister deficit countries—especially with the present trends in population growth—may be able to make themselves increasingly independent of foreign supplies. The supply of new land usable for wheat in drier regions without irrigation is rather small. Part of it, moreover, will have to offset declines in existing wheat areas owing to exhaustion of the soil and infestation with weeds. Yet with the situation in deficit countries as it is, even this relatively moderate capacity of drier regions for expanding their wheat production may be continuously regarded with dismay by those who have to make a living by producing wheat in drier surplus regions. The probability that new irrigated land will go largely into wheat tends further to aggravate the situation. The aggregate share of drier regions in total world production, however, will not necessarily decline, since the drier regions of Russia have a broad domestic market for a large expansion of their wheat production.

With another policy in deficit moister countries—however

improbable such change of policy may seem at the moment³³—the situation may easily be visualized in a materially different light. Production of deficit moister countries would stop increasing or even go down, owing to (a) lesser protection of wheat, (b) the necessity of renouncing part of the possible increase in yield in order to produce stronger but less prolific varieties of wheat because of the mild aversion of consumers to bread made from weak wheats, and (c) a greater need for land for feed production. Yet the fact that the possibility of increasing wheat production in drier regions is not so very far from the limit can hardly become a factor of significance in the foreseeable future, especially since this limit can be considerably extended by an improvement in ratios between prices of strong wheats to prices of other grains—even so small an improvement as to be scarcely noticeable by ultimate consumers of bread. In spite of the predominantly “mining” character of wheat production, the danger of a real and persistent tightness in wheat supplies seems to have been eliminated—perhaps forever—by the greatly reduced rate of increase in population numbers.

The outlook for the distribution of world wheat production between moister deficit and drier surplus countries implies developments in international trade. With the present policies in importing countries, a further contraction in the level of world exports is not improbable, but stagnation for some time is more likely.³⁴ World wheat exports cannot be expected again to rise to the level that prevailed in the predepression years, even if protection in importing countries should be cut to the level of those years, though under these circumstances a considerable portion of the loss would be regained.

³³ No one can yet predict what modifications in trade policies will be made after the end of the hostilities that broke out in September 1939, after the present manuscript was completed.

³⁴ Barring, of course, a temporary expansion resulting from devastation and other forms of deterioration which the new war may bring about.

CHAPTER XX

RYE

USES

Aside from wheat, rye is the only grain possessing the property of retaining gases in the baking process, but this ability is much less than that of wheat. Owing to this difference, and still more because of the poorer digestibility of rye bread, it tends at most to be retained as a minor substitute for wheat bread, eaten for a change or together with specific foods. As everyday bread, it continues to be used almost exclusively in those countries with moderate to low standards of living, in which the natural conditions make it very difficult to do without rye production. Even there, rye bread usually constitutes a larger proportion of the bread consumed by the poorer population, and especially by the poorer farm population, than of the bread of the well-to-do.¹ Moreover, the tendency is widespread to prepare "rye bread" with an increasing proportion of wheat flour.

The staple consumption of rye bread in Great Britain, France, Belgium, the Netherlands, and Switzerland, where it was formerly more or less important, has been discontinued. Rye bread as everyday bread is retained almost exclusively in north central and northeastern Europe, including most of Germany and Czechoslovakia, Austria, Poland, Scandinavia, the Baltic states, and northern and central Russia. In the United States, except locally, rye bread is only a minor type of bread used chiefly by immigrants from rye-eating countries and their descendants. Moreover, according to its ingredients (about $\frac{1}{3}$ of rye flour and about $\frac{2}{3}$ of wheat flour) and according to the method of preparation (the bread is almost exclusively made by the yeast rather than by the sour proc-

¹ The situation in Germany may be regarded as typical. It is illustrated in Chart 9 of "Wheat Problems and Policies in Germany," *Wheat Studies*, November 1936, XIII, 105.

ess), rye bread as used in this country is more correctly described as rye-flavored wheat bread.

Practically no rye is used as food in a form other than the common bread or, to a very small extent, flatbread.

The standing of rye as a feed grain is even less favorable than as a bread grain. There is no type of animal for which rye is considered as desirable a feed as some other grain. More or less vigorously, it is objected to for every use. Least objectionable is the use of rye as hog feed in a mixture with other more palatable and more easily digested grains such as corn and barley, or with potatoes.

Since rye as a material for breadmaking cannot be efficiently replaced by any grain other than wheat, consumers are prepared if necessary to pay for rye intended for bread more than for feed grains; but the amount of rye consumed for food would become almost negligible if rye prices were for a long time at the level of wheat prices. In regions not accustomed to the use of rye as feed, rye must be very cheap in order to induce such use of it. Even where consumers are familiar with the feeding value of rye, this grain tends to fetch slightly lower prices for feed use than those paid for other feed grains.

YIELDS AND COSTS

Rye is extremely modest in its requirements as to soil and climate. It can be grown on light soils which are unadapted to any other small grain. Rye does relatively well on strongly acid soil and it withstands all kinds of ravages of weather except heat. Rye is the most winter-hardy of all grains. But it is also the grain which responds least to luxuriant growing conditions; this applies both to rye grown on naturally good soil, and to its response to application of fertilizer in every form and also to many other cultural practices.

The large amount of straw per unit of grain may have something to do with the poor response of rye to cultural practices. The same reason contributes to the fact that rye ranks

low in yielding power, sharing with wheat the lowest two places in the ranking. Owing to its small yielding power, rye makes a poor showing in cost of production on better soils, and in this regard is not always superior even to wheat, of the grains here studied the most expensive to produce.

Except on very light soils, rye seems to be almost everywhere more expensive to produce than oats. On soils suitable for barley, winter barley also can be produced more cheaply than winter rye. The superiority of winter barley over winter rye is great in drier and especially in hot and drier climates, but winter barley retains an advantage even where rye is not affected materially by high temperatures. Spring barley also mostly costs less to produce than winter rye in drier climates, while the costs are approximately the same on intensively cultivated better soils in moister climate. But spring barley, in the growing of which special care is given to attain the highest malting quality, may cost sensibly more to produce than winter rye. Where temperature conditions are favorable to corn, this grain is far superior to rye in cost of production.

Wheat is the only grain which rather consistently costs more to produce than rye. Where winter rye in a rather cool climate competes with spring wheat on soils adapted to the latter, wheat may be more expensive in production by some 20 per cent; a little rye in these conditions may perhaps be still cheaper to produce. Where both grains are sown in the autumn on good soil and in addition the methods of crop production are intensive, the advantage in favor of rye is reduced to possibly 5 to 10 per cent and may almost entirely disappear. In hot climates, winter rye enjoys hardly any material advantage in cost of production over wheat, unless winterkilling of this is much larger than that of rye. But on soils which do not contain nutrients in readily available form, wheat as well as barley grown without fertilizer would cost far more to produce than rye. The same is true of unlimed, strongly acid soils.

The cost of production of rye on better soils has long been

too high relative to its use value. Hence rye production has been increasingly limited to areas where natural conditions, and especially soil conditions, make it difficult or even impossible to grow something else. Owing to its moderate requirements as to the conditions of the soil, some rye is grown on better soils as a desirable rotation crop, but the proportion of rye so grown seems to be small as compared with that grown because of unadaptability of the land to more exacting crops. Improvement in agricultural technique, especially combined with intensification of production, seriously weakens the competitive position of rye.

WORLD PRODUCTION AND PRODUCTION REGIONS

The amount of land of the poor quality on which rye, alone or in rotation with other inexacting crops, proves preferable to other grains is so large in the world as to insure rye a substantial share of grain acreage and production. With around 100 million acres and 1,000 million centals, rye was superior to barley and ranked fourth in world acreage and production (ex-China) in 1932-36 (Tables I and II).

An even larger proportion of rye than of oats is grown in moister climates. Rye acreage grown in drier climates may be as small as 10-15 per cent of the world total.

Another feature of rye is that almost 95 per cent of the world acreage is found in Europe and almost 60 per cent of the European rye acreage is in Russia.

Russia.—More than three-quarters of the Russian rye acreage, or approximately 45 per cent of the world rye acreage, is located in the so-called non-chernozem region with its poor forest soils, moderately or strongly leached. Those soils are unadapted for any other major grain except oats. In fact, rye and oats, with or without fallow as the occupant of the third field, have been for centuries the only grain crops grown over that vast territory—except for some barley in the far north and the even less exacting buckwheat. Quite recently, strenuous efforts have been made to introduce wheat in these

regions, but even the official enthusiasts do not go so far as to expect that the dominant position of rye (and oats) can be materially impaired there. This is clearly indicated by Chart 22 (p. 217), which shows the zoning of agricultural Russia as it is expected to be after the reorganization plans are carried out. The acidity of the soil, it is hoped, can soon be overcome by liming. But it is realized that wheat can yield reasonable crops only with application of large amounts of manure and/or artificial fertilizer, and these can be made available only for a relatively small acreage.² Even a small acreage in wheat is hardly profitable, moreover, and probably no wheat would be grown without governmental compulsion.³ In any case, the penetration of wheat into regions with poor forest soils, inhabited by poor populations with a low consumption of animal products and hence small production of manure, can be only an exceedingly slow process, especially in a grain-surplus country like Russia.

While the predominant position of rye (and oats) in the Russian non-chernozem region has been due almost exclusively to natural conditions, the large acreage of rye in the chernozem region in the recent past had its primary cause in the backwardness of the farm population. This was clearly evidenced by the well-known fact that the proportion of acreage in rye on large estates was much less than on peasant lands. Another proof is the ease with which the Soviet government succeeded in contracting the rye acreage in that region, although several similar campaigns either failed entirely or were crowned with only moderate success. As a result of the efforts, the total acreage in rye in the USSR declined from 71.3 to 58.0 million acres within the short span from 1930

² M. M. Lapin, "Wheat in the North and Methods of Its Cultivation" (*Agriculture of the USSR, 1935* [translated titles], Moscow, 1936), pp. 94-101. Lapin recommends (p. 99) the following huge amounts of manure per acre as desirable for wheat: 8 to 12 metric tons on degraded chernozems, 12 to 16 metric tons on gray forest and similar soils, and 16 to 20 metric tons on still lighter soils.

³ Such manure as can be made available is more profitably applied to potatoes and similar crops which utilize it better than any grain.

to 1935.⁴ The position of rye is hopeless in that portion of the chernozem region where winter wheat can be grown, except on light soils that are not rare even in the chernozem region. In the other portion of the region, rye at least possesses some managerial advantages as the only crop which can be sown in the fall.⁵

Other Europe.—In respect to rye growing, approximately the same conditions as in the non-chernozem region of Russia are met in a large portion of Poland, the Baltic states, and Finland, which between them have another 15 per cent of the world rye acreage.

Rye production is also greatly favored by soil conditions in Germany, which accounts for about 10 per cent of the world acreage. The high degree of intensity of production methods and the dense livestock population, it is true, enabled Germany to produce grains other than rye and oats on some of the soils on which countries with more extensive methods of crop production are compelled to stick to these two grain crops exclusively, and Germany actually does grow considerable amounts of wheat on such soils. Moreover, the process of converting land unsuitable for wheat into land on which wheat can be grown is going on in Germany at a much more rapid rate than farther east.⁶ But the intensive methods of

⁴ V. P. Timoshenko, "Soviet Agricultural Reorganization and the Bread-Grain Situation," *Wheat Studies*, April 1937, XIII, 334. See also V. P. Timoshenko, *Agricultural Russia and the Wheat Problem* (Food Research Institute, Grain Economics Series 1, Stanford University, Calif., 1932).

⁵ A further reason for retaining some acreage in winter rye may be the idea—apparently widely held in Russia—that winter rye is difficult to dispense with in its role as a good crop to precede durum wheat, which is highly valued in Russia for breadmaking. This point of view explains the fact, which may come rather as a surprise to the American student, that winter rye rather than spring wheat gets the privileged place after fallow in that portion of Russia. But the disadvantage of the low return of rye is well recognized. It is not at all impossible that the small rye acreage will be contracted further by the use of other crops to precede durum. This is especially likely to happen, if the preference for durum wheat as against strong common wheat should weaken.

⁶ This is clearly demonstrated by the fact that the German wheat acreage has expanded by about 20 per cent as compared with the last prewar years, while the rye acreage has declined by more than 10 per cent, though the price ratio between wheat and rye in postwar years was not more favorable to wheat than in the latest prewar years. See Chart 3 (p. 11) of this study as well as Chart 6 in "Wheat Problems and Policies in Germany" (*op. cit.*), p. 91; that study presents some details on the competition of rye and wheat in Germany over a longer period of years.

crop production followed in Germany enable it also to use for this purpose soils so poor that they cannot be used for crop production in countries following extensive methods. While much better land has been turned over to wheat, millions of acres of almost sterile sand have been added to the German crop acreage in the last four or five decades. It is unsuitable for wheat even with the amplest applications of fertilizer, and much of it cannot be used for any crop but rye and the poor-land lupine. Since, moreover, rye (and oats) production was extremely favored by the tariff, the rye acreage even expanded materially in prewar years.⁷

A development similar to that observed in Germany, but minus the tariff protection, is found in Denmark and, with some modifications, in some other countries of north central and northwestern Europe. The extremely poor land of western Jutland, Denmark, has been brought into cultivation with the immense amounts of manure supplied by the famous Danish animal population; and rye, having been expelled from its former home by wheat, found a new, more modest home there.⁸

A steady decline of rye acreage can also be observed in the Netherlands and Belgium, yet rye still remains important in both countries. In the Netherlands it ranks first among the grains in acreage, in Belgium it is second only to oats (Chart

⁷ See *Die Zukunft des Roggens* (Vierteljahrshefte zur Konjunkturforschung, Sonderheft 20, 1930), p. 59.

⁸ More modest, because it is much smaller and the soil is of the poorest sort. The acreage in Denmark has been reduced by about 40 per cent since the early 1880's. The limiting of rye to soils so poor that only a few decades ago they remained unused for crop production, in such an old and densely populated country as Denmark, is revealed with striking force in figures on average yields. The following data, in 100 kilograms per hectare, are from Einar Jensen, *Danish Agriculture* (Copenhagen, 1937), p. 390:

Grain	1875-79	1894-98	1929-33
Wheat	21	26	29
Barley	15	16	28
Oats	11	13	26
Rye	16	16	17

While the average yields of other grains increased 38 to 136 per cent since the late seventies, the average yield of rye remained practically unchanged in the face of tremendous increase in intensity of crop production over the period. In recent years, rye yielded only 59 per cent as much as wheat. This yield ratio testifies to the poor quality of the soil upon which rye is grown now.

61, p. 494). In fact, in the British Isles are found the only countries in northern Europe which have entirely ceased to grow rye. This continuation of rye production in northwestern Europe in the face of the discontinued consumption of rye bread is quite remarkable. Taylor's assertion, that "Raising rye is agriculturally advantageous, but selling [better say utilizing] the crop tends to be economically disadvantageous,"⁹ applies well to the situation in the north of continental Europe.

The striking difference between Britain and Belgium is probably largely explained by soil conditions (in the former, "rye" soils are seldom used for crop production) and by the high evaluation of wheat as feed in Great Britain. But rotational requirements probably also play a role. It was shown that rye and oats are practically not competitors in north central and northeastern Europe, being the best combination of crops for the prevailing type of soil. Farther west, where both intensive methods of crop production are in vogue and land is used intensively (relatively little arable land is in grass but much in roots and potatoes), both grains can still find a comfortable place in the same rotation on poor soils. But where, as in Great Britain, cultural practices are intensive but the land is used extensively (much arable land in grass), one of the grains suffices to be rotated with grass. Oats and rye become competitors and oats win; in moist climates they seem to win quite regularly over any other grain.

Farther south, rye production becomes ever more easy to dispense with, owing to the objection of rye to heat and to the availability of other crops. In France rye has been reduced to a small acreage either on the high plateaus in south central France or on the sandy soils of Brittany and elsewhere.¹⁰ Moreover, rye has long been in the position of being grown only on the poorest land, improvements in technique per-

⁹ A. E. Taylor, "Rye in Its Relations to Wheat," *Wheat Studies*, March 1928, IV, 184.

¹⁰ See chart on p. 15 of *Die Zukunft des Roggens* for a regional distribution of the rye acreage in France.

mitting more exacting grains to make constantly fresh inroads upon the rye acreage.¹¹ The situation in Spain, Portugal, Hungary, and many other countries is similar to that of France. No rye is grown where conditions are adapted to corn, which also can be grown on lightest soils.

Non-Europe.—While in Europe rye production has been unmistakably declining, it has made substantial gains in all three countries where it is grown outside of Europe. In the United States, Canada, and Argentina, the rye acreage expanded after the outbreak of the World War and, though reduced later, continues to be much larger than before the war. At best, nevertheless, ex-Europe has remained a minor factor in world rye production.

All of the immense territory north of the borderline of corn penetration in North America, from the Atlantic Ocean almost to the western border of Minnesota, resembles in soil and climate—in reversed order from east to west—the wide area extending from Belgium to the border of Asia where some 90 per cent of the world rye production is located. The proportion of soils unsuitable for wheat and barley, although not so small in the delineated area of North America as it is in the corresponding area of Europe, is still very large, especially if it is recalled that in Canada crop production and colonization in general did not penetrate so far into the cold north as in Europe. In both the European and North American area, rye is mostly the only grain which can be grown as a winter crop.¹²

While largely similar in natural conditions, the two regions nevertheless differ greatly economically, in the density of population and the standard of living. Were northeastern North America as densely populated as the European rye area, and its population largely compelled to eat the bread that its soil can produce, two more rye producers of the rank

¹¹ From the early 1880's, the rye acreage in France has declined by approximately two-thirds.

¹² See also A. E. Taylor, *op. cit.*, p. 189.

of Germany might be present. Actually, however, the importance that rye ever reached in the eastern United States was only moderate,¹³ while in eastern Canada rye production never exceeded a few million bushels; on both sides of the international line, rye has almost entirely disappeared.¹⁴

When rye production in northeastern North America, where climate and much soil are particularly adapted to it, had become a negligible factor if it had ever been anything else, it might have been supposed that the final word in the history of American rye production had been spoken. Yet at that very time a rye industry was suddenly established in the home of wheat, in the hard-spring-wheat belt of the United States and Canada. A phenomenal extension of rye acreage from 368,000 acres in 1914 to 2,542,000 acres in 1922 took place in the Dakotas. It averaged 1,578,000 in 1924-28 and still amounted to 1,181,000 in 1937. Owing to this increase, the rye acreage of the United States was nearly three times as large in 1918 and 1919 as immediately before the World War. The increase has been reduced by some 70 per cent since, it is true. In the Prairie Provinces the rye acreage jumped from 71,000 acres in 1916 to 1,926,000 acres in 1922 and has since varied from 500,000 to 1,100,000 acres.

War scarcity gave the immediate impetus to this development. But rye seems also to have gained a formerly neglected, permanent, though very modest, home as a major crop on very light soils, and occasionally also as a subsidiary crop on better soils. It may prove strongest as a subsidiary crop on lighter types of soil.

Even at the most favorable price ratios to wheat which occurred after the outbreak of the World War, rye could hardly compete with wheat as a major crop on better soils of the region, and only temporarily if at all. As a major crop rye

¹³ See Figure 80, p. 354 and Table 42, p. 355 of P. W. Bidwell and J. I. Falconer, *History of Agriculture in the Northern United States, 1620-1860* (Washington, D.C., May 1925).

¹⁴ The reasons are probably the same as in Great Britain. Oats are sufficient for—and superior to rye in—the rotation with hay widely grown in that region, owing to better suitability of oats as a cover crop and as a feed supplementary to hay.

finds a place only on lightest soils such as are seldom used for crop production in the region involved.

On better soils rye must compete strongly even for a modest place as a subsidiary crop. Being the only winter crop of the region, rye can claim considerably more managerial advantages than barley and especially oats. But the extra advantages are offset by the unfavorable effect of rye on the market value of wheat which follows it in rotation.¹⁵ Since the extra managerial advantages are offset, the competition of rye with barley and oats is decided by the relation between their price and cost ratios as computed in chapter xvi (pp. 389-90 and 394-96).

According to those computations, barley costs some 10 per cent less to produce than rye in North Dakota and the Prairie Provinces. But there is no reason for rye to fetch higher prices than those paid for barley, unless it finds sufficient demand for human food. Rye as a subsidiary crop makes a somewhat better showing in competition with oats. But oats themselves have no strong footing in the hard-spring-wheat belt of North America, unless needed for the farm horses. Experience showed in fact that rye acreage dropped materially after the European demand, which was for food, ceased late in the twenties.

The close association between poor soil and rye growing in the hard-spring-wheat region can be observed in Chart 33 (p. 265). In North Dakota, for example, most rye is concentrated in the central portion of the state. But contrary to the impression created by the chart (this impression is the result of using a rather large dot for every 2,000 acres of rye), rye does not become the dominant crop even in counties with the greatest proportion of lightest soils. Indeed, rye acreage is sufficiently important to have been included in

¹⁵ Rye volunteers readily, and consequently appears as an admixture with wheat; this admixture cannot be separated from wheat in the ordinary cleaning process, and therefore lowers the grade of the wheat. The statement applies mainly to common wheat, not durum. The crop combination fallow-winter rye-durum wheat may be found of value in some of the areas less adapted to common spring wheat, for reasons other than shortage of the growing season.

Chart 49 (p. 449) in second place only in one county of the hard-spring-wheat region of the United States, namely McHenry County, North Dakota. It is significant for the long-run standing of rye that the use of lightest soils for crop production is likely to be ultimately discontinued in that portion of North America.

The association between light soils and rye seems also to be the most important reason for the fact that the rye acreage is relatively much larger in North Dakota than in the Prairie Provinces (in 1937, 6 per cent of the grain acreage was in rye in North Dakota as against 2 per cent in the provinces).¹⁶

Argentina harvested 85,000 acres of rye on the average in 1909-13 and 759,000 acres in 1933-37. But the rye grain produced there is mainly a by-product of the livestock industry. It is grown for pasture, and leftovers that are not needed for pasturing, owing to good condition of natural pastures, are harvested for grain and shipped abroad (p. 400). Even for such purposes, rye seems to compete successfully with oats and barley only on poorer soils and in cooler climates. Although the rye grain is more or less a by-product, the falling-off of the European demand for food in recent years was reflected in a material reduction in the rye acreage.

World production in the past.—In spite of the considerable contraction of rye acreages in many countries, in the last two decades of the nineteenth century "world" rye production was still almost able to keep up with the increase in total world grain production.¹⁷ The major reasons were the phenomenal increase in yields in northwestern and north central Europe, which participated heavily in world rye production, and the addition of very poor lands to the arable acreage in that part of the world. But in the eleven years from 1898-1902 to 1909-13, rye production in the same countries to which the preceding data pertain increased only by 14 per cent as against

¹⁶ Another reason is that the competition of oats with rye is less in North Dakota owing to the much larger use of tractors there.

¹⁷ The incomplete data (for sources, see p. 496) indicate an increase in the production of rye by 33 per cent as against 38 per cent for all five grains.

an increase of 33 per cent for all five grains. Official data show that world rye production has increased somewhat since the World War, but strictly comparable data might prove that no increase occurred. Even such maintenance of level was possible only because of heavy protection given to domestic production in various countries with large rye acreages; but it should also be taken as an indication of the slowness of adjustments of the production of rye and other poor-land crops to declines in demand.

WORLD TRADE

International trade in rye has always been limited both in scope and in territory. Shortly before the turn of the century rye ranked third in world trade, the first two places being occupied by wheat and corn. In the few ensuing years up to the World War, world trade in rye was relegated to the last place (Table V).

Until shortly before the World War, Russia was the only important net exporter while the buyers were crowded around the Baltic and North seas. In the last prewar decade Russia was joined by Germany, which developed large surpluses under the protection of high import duties and export certificates.

After a renaissance in the early 1920's, net world trade in rye dwindled to about a million metric tons annually. On a comparable basis, this figure was less than half of the average exports in the five years centered around 1900. Net imports of only three countries (Denmark, Austria, and Norway) now average 100,000 to 200,000 tons annually, and a few more countries are in the class of 50,000 to 100,000 tons. The main sources of supplies are Argentina, with its by-product of rye pastures, and Poland, which owing to its soil conditions can grow little else than rye, oats, and potatoes.

OUTLOOK

Doubts with regard to the future of rye consumption and production can be entertained merely as to the rate of decline.

There is hardly a single country in which, in the long run, rye bread is likely to have a chance to retain its place as the principal bread.

If the time should return when satisfaction of the consumer is considered an important task of the statesman, the further decline in the use of rye as food will probably again be relatively rapid; and the proportion of land which cannot be used for crops more exacting than rye (and oats) will hardly decline so rapidly. Even under these circumstances, production of rye and—in even greater degree—of oats will be supported by the fact that these grains are grown, to a much larger extent than wheat and barley or even corn, in regions of increasing fertility and rising yields. This fact may steadily gain in weight as “soil mining” progressively depletes the soils in regions recently taken into cultivation in the Americas, eastern Russia, and Australia. An important additional factor that will support rye production is that, on the poor soils on which it is mostly grown, the most adapted alternative crop is oats, another grain for which the demand is falling. For neither grain are there easy “escapes.” Increasing proportions of the rye produced will not be in demand for food use and will have to be used for feed, and rye prices will more and more rarely rise above those justified by the low value of rye as feed. Rye trade in general, and international trade in this grain in particular, will decline further.

At the present writing, the prospects that the interests of consumers will be much cared for are not bright in several countries important for rye consumption and production, and, moreover, rye production there may not be permitted to go its natural way. But all this will merely postpone the inevitable.

CHAPTER XXI

BARLEY

USES

The predominant portion of world production of barley is used as feed. Unknown but substantial quantities are used, almost exclusively in Asia and northern Africa, for food in the form of flatbread or porridge. Another important use is for beer, which takes slightly more than 10 per cent of the world production.¹ In the United Kingdom, Germany, Austria, and some regions of the United States and a few other countries, the proportion of barley used for beer is several times as large. Moreover, barley used for beer affects the extent of total barley production more than is indicated by the quantity used for this purpose, because considerable amounts of barley actually used for other purposes are produced in the hope that they might be usable for beer preparation. Minor uses of barley are in distilleries as malt and as the material distilled, and as a coffee substitute.

Barley is the only grain of which the value of different types to the consumer varies so widely for reasons other than differences in the content of nutrients, that in the economic sense it may be proper to speak of two different grains. Any barley can be used for feed. The quality requirements of barley in other uses except for beer are also satisfied more or less easily; the higher grades of almost any type suffice, and frequently everything available is used. But only certain types of barley, not produced in large volume, are used for the preparation of beer. The distinction between malting barley² and other barleys is therefore pertinent.

¹ If we may trust a rough estimate from data on the use of malt for beer in the United States, Great Britain, and Germany, and otherwise from data on world production of beer in the *Statistical Year-Book of the League of Nations, 1936-37* (Geneva, 1937), pp. 102-03.

² Barley used for beer, and such barley alone, is referred to in this study as malting barley.

Barley as feed is slightly less palatable than corn and, due to its hull, contains about 5 per cent less nutrients. Except for poultry, it is primarily a fattening feed. For this reason it is liked less than oats as a horse feed. Pork production is the most important use of feed barley. Pork, ham, and bacon of hogs finished on barley are firmer than those of hogs finished on corn and are therefore at a premium in some European countries. But corn-fed hogs are not discriminated against in the United States.

Good malting barley should be sound, plump, bright in color, consist of kernels of approximately equal size, low in protein, and possess sufficient diastatic power. Only two-row barleys with the above characteristics are in general considered appropriate for beer preparation in important beer-consuming countries of Europe. In the United States, six-row barleys are used for the same purpose, but the requirements otherwise are approximately as high as in Europe. These specific requirements as to quality make malting barley a very delicate, high-priced commodity.

The quality of barley and its value for different uses are greatly dependent upon climate, to a lesser extent upon soil. As with every other grain, the moisture content of barley and the risk of harvest damage rise with increase of precipitation, while simultaneously the protein content and the diastatic power decline. It is important for barley, as also for oats, that grain grown in moister climate tends to contain a materially smaller proportion of hulls, and the kernels of such grain tend to be considerably plumper than those produced in drier climate. The soil is important for the quality of barley primarily because high nitrogen content in the soil is associated with a high protein content of the barley, which is undesirable in beer production.

A low content of hulls is a valuable feature of barley for all uses. Given reasonably good harvesting weather, barley grown in moister climates may have a greater value than that grown in drier climates, even as feed, in spite of its lower protein

content and higher moisture content. Plumpness of kernel is especially important in malting barley. The best malting barley is produced on the borderline between drier and moister regions. Barley grown in *moist* climates is ordinarily unsuitable, since a sound grain with an unimpaired germinating power and a minimum of diastatic power is believed indispensable.³ On the same ground, part of barley grown in moister climate—in some years a large part—fails to answer the rigid requirements. To avoid high protein content, soil is chosen that is not rich in nitrogen, and nitrogenous fertilizer is used with caution.

Regional variations in the quality of the barley are of great import for the competition of barley with other grains for the land, especially with wheat. In contrast with barley, the high-priced strong wheats are produced in the drier and even very dry regions. For the competition of barley with wheat it is furthermore important that the practically equal marketing costs are a much larger burden on the cheap feed and similar barleys than on the more expensive wheat. The combined effect of all factors brings it about that in drier regions usually located far from deficit regions, feed barley—in order to be on export or shipping basis to the same extent as wheat—must have a price 30 to 40 per cent below the price of wheat, whereas in deficit moister countries barley approaches wheat in price within 10 to 20 per cent. The price of barley suitable for beer production is still closer to the wheat price; in fact, malting barley of good quality frequently commands higher prices than wheat. Producers of such barley, it is true, may not get more for it than for their wheat, for a much larger percentage of barley produced in moister climate fails to pass the test for use in beer production as compared with wheat for milling. Still, prices of barley to producers usually compare favorably with wheat prices, where

³ Recently strenuous efforts have been made in Great Britain to prevent spoilage of malting barley from bad harvesting weather by harvesting with the combine and immediately drying it artificially. One of the main difficulties is that the drying must be conducted very carefully so as not to impair the germinating power of the barley.

a large proportion of the barley is used for malting and the demand is for high-quality grades of beer requiring very selective buying of barley.

YIELDS AND COSTS

Barley is a shallow-rooted, rapid-growing plant, and most varieties of it do not make good progress in a soil not sufficiently supplied with nutrients in readily available form. Hence barley needs in general almost as good a soil as wheat, and is more exacting in this regard than corn, oats, or rye. Moreover, it is more sensitive to acidity than any other grain. Needing nutrients in readily available form and having the most favorable proportion of grain to straw of all small grains, barley frequently responds most readily to fertilizer in every form. In this respect the two-row spring barley widely grown in northwestern Europe excels all other small grains, except in some cases winter wheat and oats.

Barley is grown under a great variety of climatic conditions.* Since spring barley has a shorter growing period than any of the five grains, and is also modest with regard to minimum germinating temperature and total warmth required, it approaches closer to the North Pole and climbs nearer to the sky in the mountains than any other grain. However, in winter-hardiness—a very important factor for the distribution of small grains in the world—barley exceeds only oats, being much inferior to rye and wheat. Barley withstands dry heat better than any other small grain except millet, but in moist heat does not display any superiority to oats, its principal competitor for acreage in many regions.

Barley does relatively well with little precipitation, being surpassed in this regard only by millets. The various millets, however, are grown in temperate climates only as spring grains. As a winter crop, barley there has no rivals in dry conditions. No other grain crop here studied, indeed, is

* This is not very distinct from Chart 62, because the quantities grown in many regions, for example in the eastern United States, are too small in comparison with the scale used in the chart.

grown so near the desert. But barley does not utilize water beyond the minimum as efficiently as other grains do; its optimum water saturation of the soil is low, and its ability to withstand moisture in excess of the optimum is very moderate.

Barley is superior in yielding power to wheat and rye, to some extent owing to the fact that its hulls go with the grain while the hulls of wheat and rye go with the straw; but barley is not as heavy a yielder as corn, and ranks in yielding power only about as high as oats.

The difference in yield between spring barley and spring wheat, or between fall-sown barley and fall-sown wheat in drier regions, may be as large as 40 per cent in favor of barley. This advantage can be lost entirely where in hot climates spring barley has to compete with winter wheat. The advantage that barley possesses over wheat in drier climates is also partly lost under irrigation. Fall-sown barley out-yields fall-sown wheat also in moister climates, but not to the same extent as in drier climates, while the yield of winter wheat is still closer to that of spring barley under the same climatic conditions. The advantage of spring barley in yield over winter wheat in moister climate, if any, is particularly small where intensive methods of crop production are practiced. Barley intended to fetch a high price as material for beer is likely to be regularly outyielded by winter wheat in such conditions, owing to the reluctance of producers to apply much nitrogenous fertilizer to it.

Barley tends materially to outyield oats in drier climate, ranks about as high as oats in moderately moist and moderately hot climates, but is outyielded by them in moist climates or in moister hot climates, as well as on poor soils—particularly very acid ones—in practically every climate. Under irrigation, however, barley retains its superiority in yield over oats, because the hot, dry air of the irrigated areas and their tendency toward alkalinity are not favorable for oats.

The cost of producing barley relative to that of the other grains runs largely parallel to yield. Where climatic con-

ditions are at least moderately fair for corn, this grain is much cheaper to produce than barley. In drier regions, where spring barley competes with spring wheat or fall-sown barley competes with fall-sown wheat, barley may be cheaper to produce than wheat by as much as 20 to 30 per cent. In regions with moister climates practicing intensive methods, the advantage in favor of fall-sown barley is hardly larger than 15 per cent and may be somewhat less. Where, under the same conditions, spring barley has to compete with winter wheat, the cost of producing barley is likely to be only slightly less than that of wheat. Two-row malting barley of the best quality produced under unfavorable climatic conditions may involve even higher costs than winter wheat. Barley other than malting barley is in general cheaper to produce than oats where it yields the more heavily, and vice versa.

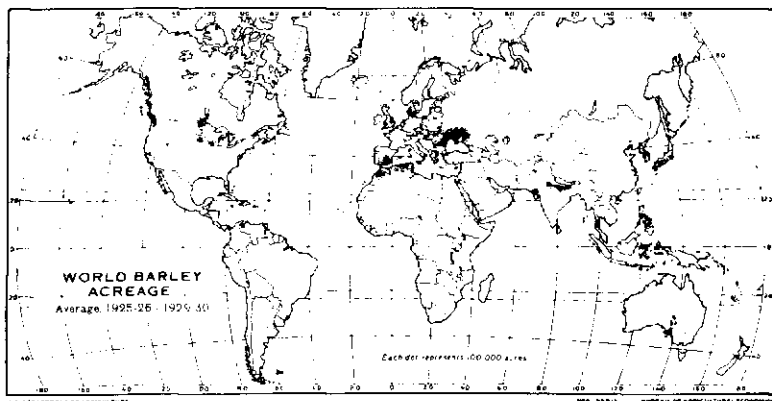
WORLD PRODUCTION AND PRODUCTION REGIONS

The advantage of barley over wheat in yield and cost of production in many drier regions seldom suffices for it to be the dominant or even a very important crop. Frequently the advantage is just enough for the modest role of a crop subsidiary or secondary⁶ to wheat, the dominant crop of such regions. Moreover, barley is almost absent in moderately dry regions with summer rains and temperature adapted to corn, as well as in hot regions with summer rains adapted to sorghum. In moister regions barley in general can boast substantial acreages only as malting barley or, to a like extent, as winter barley. Barley therefore ranks last among the grains studied in both world acreage and world production (Tables I and II).

In drier regions.—Of the approximately 85 million acres in barley in the world ex-China, about 70 per cent is in drier regions (Chart 62). This percentage includes barley grown

⁶ Subsidiary in the sense that the crop is grown together with the principal crop owing to rotational and/or managerial advantages; secondary in the sense that the crop is grown on a smaller acreage than the principal crop as a subsidiary crop or for its own sake—even in monoculture.

CHART 62



under irrigation. The percentage of barley acreage grown with insufficient moisture may be slightly less than the percentage of wheat acreage grown under such conditions.

About half of the 60 million acres of barley grown in drier climates is located in regions with sufficiently warm climates for the barley to be sown in the fall or winter (California, countries around the Mediterranean, British India, Argentina, and so on). Almost all these regions are those with Mediterranean or similar climates, so far as growing conditions for wheat and barley are concerned. The competitive position of barley in those regions has been discussed in chapter xix (pp. 486-91). With only minor exceptions, barley is grown in all of them for its own sake, rather than for rotational or other considerations. Wheat is the principal competitor. Although barley is strongest in competitive power where it is grown with insufficient moisture as a fall-sown crop, considerably more than twice as much wheat as barley is produced under these conditions. Barley is the victorious crop in California owing to the scarcity of feed in that part of the country, and to the fact that the quality of wheat produced there does not satisfy the high requirements as material for bread. Almost as much barley as wheat is grown in French northern Africa, largely because of the extremely low standard of living of the population and the backwardness of the

producers in agricultural technique. But barley is much less important than wheat in Spain, British India, and many other countries. In all of these, barley occupies the driest lands and the poorer, especially the more weedy, lands—in British India also the most elevated lands. Although climatic conditions in the Australian wheat belt do not differ much from those of the countries described, fall-sown barley fails to get a foothold in the drier portions (see p. 299).

Some 10 million acres of spring barley are grown in the hard-spring-wheat belts of the United States, Canada, and Russia in competition with spring wheat (and spring oats). There barley is found almost exclusively on lands which have become too weedy for wheat, grown continuously or alternated from time to time with fallow. It is of considerable interest that approximately four-fifths of this acreage is in the hard-spring-wheat belt of North America and only one-fifth in the Russian belt, although the latter is the larger. Spring barley, which on this side of the ocean successfully competes with spring oats in the hard-spring-wheat belts of both the United States and Canada, displays the same power on the other side of the ocean only in the southwestern portion of the Russian belt. The explanation offered on page 269 for this divergence may be inadequate or insufficient. One cannot refrain from thinking that the high yielding power of varieties of barley adapted to those regions, and especially its usefulness as a mild weed-combater, are not sufficiently realized in Russia.⁶

Almost 20 million acres of spring barley are grown in the hard-winter-wheat belt of this country and in comparable regions of Russia and drier portions of the Danubian countries. The competitive position of barley in the hard-winter-wheat belt of the United States is considerably lower than in its hard-spring-wheat belt. The relatively large acreage of spring

⁶ Barley in this role is not even mentioned in the study by M. S. Kusmin, N. G. Samarin, and N. M. Tylajkow. *The Problem of Alternate Sod and Rotation in Wheat Husbandry* [translated title] (Moscow, 1930), published by the Institute for Combating Drought in RSFSP and approved by the Committee on Yields of the Commissariat of Agriculture of the RSFSP.

barley in the drier regions of Russia and the Balkan countries growing winter wheat should probably not be taken to indicate that the situation is reversed there. The unprofitableness of barley in most portions of the Russian winter-wheat belt is officially recognized, and energetic measures are being taken to replace it by other crops—so far as compatible with climate, by corn. In recent years, the Russian barley acreage has been about 20 per cent less than in the last pre-war years. At a slower rate, the same trend can be observed in Rumania, which has almost three-quarters of the total Danubian acreage in spring barley.

In moister regions.—About one-third of the barley acreage of the world ex-China is grown in moister climates (some 18 million acres in Europe, some 5 million in the Far East of Asia, and some 4 million in the United States). A large portion of the spring barley grown in the moister regions of Europe consists of two-row barley and is to a large extent used for beer production. In any case, most of those barleys have a chance, if they happen to be harvested in good condition, to fetch a materially better price than that obtainable for feed barley. If the inference is correct that the cost of producing spring barley in moister climates by intensive methods is only slightly less than that of winter wheat (see the computation for Germany in Table 25, p. 411, and Chart 61, p. 494), the production of large quantities of spring barley specifically for the use as feed, is indeed unprofitable under the present price relationships.

Barley produced in moister portions of Europe without a hope for a price above that of feed barley is mostly winter barley. The yielding power of winter barley, considered in relation to the usual price ratios in western European countries, would justify a much larger production of it than is actually the case (see Table IV). Only the German acreage in winter barley, however, has shown an increase in postwar years—indeed, a surprisingly large increase;⁷ but this has

⁷ From 107,000 hectares in 1924 to 197,000 in 1930 and 439,000 hectares in 1937.

been due to exceptional circumstances.⁸ The failure of all other countries to expand their acreage in winter barley may be accepted as a proof that the limits set to its production by the meager winter-hardiness of barley have been approximately reached.

A large portion of barley produced in moister regions of the United States—mostly in Minnesota and Wisconsin—has a considerable chance to be used as malting barley and to fetch fancy prices. Since these barleys are six-row barleys, on adapted soils and in adapted places in rotations they can probably be produced at approximately the same cost per pound as oats. The much higher returns in recent years for barley used in malting has probably brought it about that less adapted soils and less adapted places of rotations are used for barley.⁹

The barleys—both common and naked—of Japan and Chosen are the higher-yielding fall-sown barleys. Moreover, almost all of them are used for food, to a large extent by the producers themselves. In spite of all this, barley in Japan has for a long time been a less profitable crop than wheat, and a shift from barley to wheat could be observed.¹⁰

The irrigated acreage in barley is only a fraction of that in wheat, although the regions where most irrigated wheat is located grow much barley in dry farming. The much lesser importance of barley on irrigated land is in agreement with our supposition that relieving the scarcity of water reduces the superiority in yield that barley has over wheat under a small supply of water. Barley is not so weak in the irrigated areas of the United States as elsewhere. There is a shortage of concentrated feeds relative to the huge amounts of pasture

⁸ Before the World War, price ratios did not justify the production of any barley for feed in Germany. In recent years, the expansion of the acreage in winter barley was stimulated by the shortage of feed grains, which was not correctly reflected in the fixed prices.

⁹ The acreage in barley has doubled in Minnesota and Wisconsin since 1925.

¹⁰ See Wen Yuh Swen and C. L. Alsberg, "Japan as a Producer and Importer of Wheat," *Wheat Studies*, July 1930, VI, 351-78, and C. L. Alsberg, "Japanese Self-Sufficiency in Wheat," *Wheat Studies*, November 1935, XII, 57-100.

and livestock in the regions where most irrigated land is located. Since corn is handicapped by low temperatures, and managerial considerations also do not favor it, barley frequently gets the choice.

WORLD TRADE

The development of the international trade in barley was discussed in some detail in chapter xviii. It was shown that barley greatly exceeded all other grains in the rate of increase in world exports during the last 35 prewar years. In the latest prewar years world exports of this grain were only about 20 per cent less than those of corn.¹¹ It was, however, also pointed out that this trend was brought about by factors the effect of which could not last. Such were the tremendous expansion of the barley acreage in Russia and the Danubian countries within a short span of time; the lessening of the competition of corn, due to the withdrawal of the United States as an export country at a rate which could not be offset by the enlargement of exports from other surplus countries; and the preference given to barley in the German tariff in effect from March 1, 1906 to the beginning of the World War. In recent years, in fact, world exports of barley fell off to only slightly more than one-third of the prewar exports and were less than one-quarter of the world corn exports, the latter having been materially expanded in the meantime (Table V).

OUTLOOK

Where per capita consumption of beer is large, as in Germany, its long-time trend seems to be downward. The large increase of beer consumption in the United States in recent years is simply the continuation of the process which started after the repeal of prohibition. Data compiled in the *Statistical Year-Book of the League of Nations* indicate that beer consumption in countries where it is small does not show a

¹¹ This percentage is based on data for prewar boundaries of the countries involved.

tendency to increase significantly. Utilization of barley for food will probably decline—at least relative to that of wheat—both where barley provides the chief cereal food and where its consumption has already been reduced to a very modest role.

The only substantial help for barley from the demand side, which seems not entirely improbable, is an increase in the discrimination against hogs fed on corn. If such a discrimination should become widespread in the United States, it would create quite a revolution in feed-grain markets.

Barley acreage will probably expand considerably in Saskatchewan and Alberta, particularly in their more northern portions. One cannot be so confident with regard to the development in the hard-spring-wheat region of this country. It would not at all surprise the writer if barley would find access to the vast portion of the Russian spring-wheat region,¹² where it is now grown hardly at all, as a crop whose adapted varieties yield better than oats in similar conditions in North America and help also to combat the weeds so burdensome in those regions. Barley may furthermore get a foothold at least in the dry portions of Australia. On the other hand, reductions in the barley acreages at some future time are not unlikely in northern Africa and Asia, where barley is largely grown for use as food, and in part on very poor and/or very dry lands. A decline in barley acreage in Rumania and the winter-wheat belt of Russia is also likely.

The proportion of land adapted to barley in moister regions is constantly increasing through the more extensive use of liming. Spring barley may therefore be expected slowly to gain some territory at the expense of oats in those regions, even with price ratios unchanged. But an improvement in the price of barley relative to wheat and/or oats seems not improbable, owing to consumers' objections to bread made of wheat grown in moister climates and to the disproportion be-

¹² The writer made an effort to get a reaction from Russia to this statement but failed.

tween the supply of and the decreasing demand for oats. Expansion of the acreage in winter barley in moister climates is primarily a question of improving its frost resistance. Breeding of more winter-hardy varieties of barley would bring about a material expansion of its acreage in many regions. All in all, barley may about retain its share in total world grain production.

A restoration of the prewar volume of world barley exports is very unlikely, owing to fundamental changes in the economy of Russia, the dominant prewar exporter, and considerable changes in Germany, the dominant prewar importer. Exports are more likely to continue on the moderate side, consisting—contrary to the prewar situation—to a large extent of occasional surpluses of regions with large year-to-year variations in yields.

OATS

USES

Oats are still used as food in the form of porridge in some countries, mostly northern ones. There the demand for this purpose may sensibly affect the prices of the top grades of oats. But the proportion of oat production used for food is much less than that of any other grain, and the feed value of oats is the only important factor in determining their position from the demand side.

Oats, like barley a hulled grain, contain about 15 per cent less nutrients per cental than does corn; but otherwise, oats are an excellent feed. They are highly valued for milk cows, sows, and other types of animals except hogs in the fattening stage; large amounts of oats are used for these purposes at prices sensibly higher than in proportion to content of nutrients. Oats are unanimously acknowledged as the horse feed par excellence. Though even here other grains can be substituted, horse owners in many countries are prepared to pay for oats considerably more than for any other feed grain; the demand for use by city and especially army horses is particularly inelastic. Many farmers grow oats for their horses even where oats cost appreciably more to produce than some other feed grain. Since a large portion of oats production, in some regions almost all of it, is or was some time ago used for horses, this use is very important as a factor determining oats prices. Motorization of road transport and of farm field work has therefore been a big blow to oats. Before the motorization, oats cost more than any other feed grain; now, except perhaps for rye, the opposite is true. For the same reason, oats prices tended and to a lesser degree still tend to display the greatest independence from the short-run changes of prices of other feed grains.

The feeding value of oats straw is superior to that of any other straw. This enhances the total value of the oats crop and plays some role in the competition of oats for the land.

Like barley, oats produced in moister climates are superior in quality to those grown in drier climates. Cool, moist, foggy climates seem to produce the best oats. Oats grown in Scotland, for example, are famous. The improvement of the value of oats in moister climates is even larger than that of barley in all uses other than in beer production. The fine quality of oats grown in cool, moist climates is of immense significance for their competition for acreage, especially since this effect is cumulated with the effect of several other factors. Thus (*a*) the quality of wheat deteriorates greatly where moisture supply is large; (*b*) the marketing costs, involving long water hauls or much handling in elevators and warehouses, are higher to considerably higher on oats than on any other grain; and (*c*) oats which grow relatively well in moist climate are the best feed supplement of hay and pastures, which also thrive well in such climatic conditions and are therefore frequently the principal or even exclusive occupants of farm land in such regions.

Under the combined effect of all these factors, oats tend to cost only 60–70 per cent as much as wheat in distant drier surplus regions (Chart 2, p. 10), and at these price ratios wheat may be continuously on an export basis, while oats may be not sufficiently cheap to permit exports except sporadically. In the northwestern corner of Europe, however, provided the price ratios are not distorted by tariffs, good oats are worth as much as domestic wheat while the prices of average oats are close to the latter (see the price ratios in Great Britain, Belgium, Denmark, and, for the two earlier periods, the ratios in the Netherlands in Chart 3, p. 11).

YIELDS AND COSTS

In our general ranking according to yield, oats have been placed beside barley, under corn, and above wheat and rye. But this is merely a broad generalization. Almost any of these

grains is more or less superior to the others in a certain locality, owing to the large differences in their requirements as to soil, temperature, and moisture.

Oats belong to the plants least exacting in their soil requirements. They possess the ability to make use of nutrients in a form not accessible to wheat or barley, and are less sensitive to acidity than any grain here considered. Very heavy soils, little adapted to other grains, produce fair yields of oats. In the presence of sufficient moisture, oats also do comparatively well on light soils, on which rye alone, of small grains, does better. On the lightest soils, on which corn and rye still will produce a crop, oats may practically fail. Being able to use nutrients not in readily accessible form, oats yield relatively well with little preparation of the land and even with no preparation whatever.

All the above properties insured oats an important place in production of regions climatically adapted to them when men were rather powerless against nature. Oats, indeed, still retain a significant place on poorer soils, especially on sour soils, and in very moist climates, as well as in the places in rotations for which an inexacting crop is desired because of lack of time for the preparation of the land or other reasons. But much more than rye, the other important crop under poor conditions, oats have displayed an ability to make efficient use of a rich environment. Scientific and especially intensive agriculture, which in the final analysis eliminates rye or at least greatly contracts its sphere, affects oats to a much lesser extent. Oats, in fact, are rather responsive to good soil and good soil preparation. Although responding to fertilizer less vigorously than barley, oats seem to be materially superior in this regard to rye. Under certain conditions, oats respond to certain types of fertilizer even better than does winter wheat. The strong response of oats to phosphatic fertilizer in moist northern countries is of particular importance in the struggle of this grain for survival.¹

¹ Under very moist conditions this fight is usually not with another grain, but is for the preservation of grain growing generally, oats being the only grain grown.

Oats are a cool-weather plant. They do better with little sunshine than any other grain. But oats have also displayed a certain ability to adjust themselves to higher temperatures. In moister climate they can withstand heat better than or at least as well as barley. In dry heat, it is true, barley does better than oats, and fall-sown wheat also is superior to fall-sown oats in this regard. But oats are much inferior to corn in ability to withstand heat.

An important temperature limitation upon the distribution of oats is that they are the least winter-hardy of the four small grains here studied. But there is not very much difference in this regard between oats and barley, and this similarity brings it about that in many regions, spring oats and spring barley are competitors for the same places in rotations.

Oats are materially inferior in yield to barley where moisture is scarce, especially if the grains are fall-sown. Fall-sown wheat under these conditions also generally does better—relatively and in some regions even in absolute quantities. On the other hand, oats are the small grain which does best with a very large supply of moisture; their optimum saturation of the soil with moisture is higher than for any other grain, i.e., the yield of oats continues to increase, where the other grains show declines in yield owing to abundance of water. But under irrigation oats may fail to display their superiority with an ample supply of moisture because the water supply is regulated and the air is usually hot and dry in irrigated areas.

The price ratios of oats to wheat improve greatly in favor of oats as one moves from drier surplus regions to moister deficit regions. But the ratios between the costs of producing oats and wheat on soil adapted to the latter are, in some important drier surplus regions (regions where fall-sown oats compete with fall-sown barley and fall-sown wheat, and regions where spring oats compete with fall-sown wheat), approximately the same as in some important moister deficit regions, and may be even less favorable to oats in the drier re-

gions. Even in those drier regions in which the situation is most favorable to oats, their advantage in cost of production relative to wheat is only slightly greater than it is in moister climates. While, to be on an export basis, oats should be within 60–70 per cent of the price of wheat in distant regions, such as most drier regions are, their cost of production computed at uniform rates is at most lower by 20–25 per cent. In moister deficit regions, however, in which the price of oats tends to be within 10–15 per cent of the price of wheat, oats may be less expensive to produce than wheat by approximately the same percentage, even on better soils. On soils less adapted to wheat in moister climates, and on almost any soils in *moist* climates, the relative cost of oats may be the same as in the drier regions with cost ratios most favorable for oats, or even less.

The relation between the cost of producing barley and oats corresponds broadly with their relation in yield; barley is the cheaper grain to produce in drier regions, oats in moister regions. Oats are more expensive to produce than corn where climate is adapted to the latter; under favorable conditions for corn, the cost of producing oats may be higher by 33 per cent and more.

Thus the relationship between the price and cost ratios of grains makes it profitable to produce large quantities of oats for their own sake only in moister regions unadapted to corn—especially in moist climates and on poor soils. In moister regions adapted to corn, large acreages in oats may be justified only by great rotational advantages. In drier regions, production of oats is generally limited to the coverage of local needs for oats as horse feed as well as to soils unadapted to more exacting crops; but such soils in drier climate are mostly of the light type in which without sufficient water oats cannot be expected to do even fairly well.

WORLD PRODUCTION AND PRODUCTION REGIONS

Owing to abundance of poor soil in moister “noncorn” climates, to the fitness of oats in many rotations on the other

types of soils in such climates, to their ability to withstand a large amount of moisture, and to preference given oats as a horse feed, oats rank third in world acreage and production (ex-China), i.e., above rye and barley. The world acreage and production of oats are equivalent to two-thirds of the world corn acreage and almost 60 per cent of world corn production, in spite of the great superiority of corn in yield and in cost of production in climatic conditions adapted to corn (Tables I and II).

Drier regions.—While approximately 70 per cent of the barley acreage in the world ex-China is in drier regions, only about 20 per cent of the world acreage in oats is so located. The drier regions of Russia have about 12 million acres in oats and about the same quantity is found in drier regions of northern North America. Part of this acreage is on poorer soils unsuitable to or less suitable for wheat. The predominant portion, however, is grown on soil not only well adapted to wheat but used primarily for this crop. But the oats grown on such soils are produced almost exclusively for the horses of the farmers, and are nothing else than a semifinished product in the process of wheat production. The comparison of price ratios with cost ratios in the Prairie Provinces and North Dakota (the Dakotas have about three-quarters of such acreage in the United States) leaves no doubt that oats are less profitable to grow not only as compared with wheat but also as compared with barley (see Table 25, p. 411, and Charts 56 and 58, pp. 478 and 484). Data on the disposition of the oats crop and on recent changes in oats acreage show clearly that little or no oats are produced for the market under those conditions.

Only 15.5 per cent of the oats crop of the Prairie Provinces has been marketed on the average in 1930-31 to 1934-35. In North Dakota, 19 per cent of the oats crop was sold or for sale on the average in 1924-30,² and almost all of this origi-

² See U.S. Dept. Agr., *Farm Value, Gross Income, and Cash Income from Farm Production. Part I. Estimated by Commodities and by States, Together with Production, Disposition, and Price Data Used*, March 1930 and December 1931.

nated in the moister eastern edge of the state.³ A large portion of the small quantities sold in the drier part of the state are likely to be just surpluses over the farm needs which cannot be met exactly with the very large year-to-year variations in acre-yield usual in drier regions.

The following tabulation shows the percentage declines in number of horses and mules on farms, and of the acreage in oats, in North America's drier states and provinces most important for this cereal, in the 15 years from 1921 to 1936:⁴

Province or state	Horses	Oats acreage
Saskatchewan	23	18
Alberta	25	13
Manitoba	25	35
North Dakota	44	49
South Dakota	47	47
Nebraska	33	34
Kansas	47	13

The concordance of the decline in the number of horses and in oats acreage in three of the four states of this country is very close. Kansas is the only state in which the decline in oat acreage was much less than that of horses. More favorable prices for oats in this state as compared with those in the more northern states (see Chart 2, p. 10), and repeated unsatisfactory yields of corn, may have been important factors. The oat acreage in the Canadian provinces in general followed the changes in horse numbers, though less closely.

Moister regions.—More than three-quarters of the world oat acreage is in moister climate. The proportion of the grain acreage devoted to oats is particularly large where moisture is abundant, temperature cool, and sunshine scarce. Table I shows that more than 70 per cent of the grain acreage in Eire is in oats, and the situation is similar in large portions of

³ See O. E. Baker and A. B. Genung, *A Graphic Summary of Farm Crops* (already cited), p. 37.

⁴ Data for 1937 were used for the acreages in the United States owing to the abnormal character of 1936. Only the horses on farms have been considered—here and in the succeeding comparisons—although the decline in the number of horses in cities and towns has been relatively much larger than on farms. In several countries, indeed, horses have practically disappeared except on farms. Moreover, considerably more oats (frequently many times more) are used per nonfarm than per farm horse.

Great Britain. Oats are the leading crop also in Belgium, Scandinavia, Finland, and Latvia as well as in eastern Canada and in adjacent portions of the United States (see Chart 49, p. 449). Oats and barley hold the first two places in Denmark. Oats are second to rye in Germany, Poland, northern and central Russia, and in some other regions.

The observation that oats are predominantly grown in moister and cooler climate should not, however, obscure the fact that the quality of the soil is a paramount factor. Perhaps as much as three-quarters of the oats acreage grown in moister climates is on poor soils, unadapted to such grains as wheat and barley. In Russia alone, such acreage is likely to be in the neighborhood of 35 million acres. Almost all of the 5.5 million acres of the oats acreage in Poland, far more than half of the 7 million acres in Germany, large acreages in the other countries of north central and northwestern Europe, in eastern Canada and the United States, also belong to this group. But, of course, soil and climate are closely related.

The rotational and other advantages of producing oats in conjunction with some other crops, grown for their own sakes, are the principal reason for growing oats on better soils in moister climate. This is strikingly revealed by the fact that the largest acreages of such oats are found in the Corn Belt, where the inferiority of oats in yield and in the cost of production as usually computed is greatest. Oats are widely grown there because some small grain has to be grown together with corn, and the climate does not permit or greatly hampers the sequence corn-winter wheat. All other factors are of minor importance. For example, moving from Iowa eastward, the soil becomes poorer and moisture more abundant, both factors favoring oats in relation to wheat. Yet in the same movement the difficulties of having winter wheat after corn in rotations also become less, and we find in fact the following ratios between wheat and oats acreages (wheat acreage in per cent of oats acreage in 1937): Iowa, 14; Illinois, 72; Indiana, 149; Ohio, 195. Pennsylvania, with its predominantly poorer

soils, also grows more wheat than oats. In Missouri, located south of Iowa and much less handicapped in adhering to the sequence of corn-winter wheat, the acreage in wheat is twice as large as that of oats. Heat, it is true, is a handicap to oats in Missouri.

Oats are least in the way of the other crops in rotations. Hence the more profitable the principal crop, the more readily the farmer fills in the gaps in rotations with oats. In the Corn Belt these are least in the way of the highly profitable corn, in northeastern France they seem to be least in the way of wheat that is made extremely profitable by the tariff, and so on.

It has been shown that in drier regions oats are grown mainly owing to demand conditions, and that therefore changes in demand are strongly reflected in production. In moister climates, demand for oats frequently fails entirely to affect production, or the effect is only moderate, owing to the great dependence of oats production on natural or rotational requirements.⁵ This is true in particular of the effect of motorization of road transport on oats production.⁶

A striking example of the difficulty of replacing oats by another crop on poor soils worked by extensive methods is the fact that the present Russian oats production is larger than before the World War, while the number of horses on farms in 1937 was only 45 per cent as large as in 1916. A more or less similar situation is observed almost everywhere in moister regions growing oats. Up to the recent depression the effect of motorization on the oats enterprise in Great Britain was limited to a decline in acreage, production remaining the same. Where the production of oats has been affected,

⁵ A large portion of the oats which are produced in the heart of the Corn Belt cannot even be used to advantage on farms growing them. By far the predominant portion of oats sold or to be sold in the United States originates in Iowa, Illinois, Indiana, and northwestern Ohio (see O. E. Baker and A. B. Genung, *loc. cit.*), i.e., in regions of greatest corn concentration, unadapted for the sequence of corn-winter wheat.

⁶ In comparing the data on changes in oats production, it must not be disregarded, however, that a smaller proportion of oats produced on farms in moister climates is used for horses than is true of drier regions. Much livestock other than horses is usually kept on them, while in drier regions the livestock population on farms engaged in crop husbandry frequently consists almost exclusively of horses.

the decline tends to be considerably less than that of horse numbers. In the states of New York, Michigan, Wisconsin, and Minnesota the acreage in oats declined from 1921 to 1936 by 19, 21, 5, and 5 per cent, while the number of farm horses was reduced in the same years by 41, 37, 21, and 21 per cent, respectively. In eastern Canada, it is true, the oats acreage declined in the same years by 25 per cent.

A rather considerable amount of independence from horse numbers is shown also by oats production on good soils. In Iowa, with its huge oats crop, the acreage declined only by 13 per cent in the fifteen years 1921-36, while the number of horses and mules on farms went down by 33 per cent.

An important feature of declines in acreage of oats in cool moister regions of countries with a high standard of living such as the United States, Canada, or Great Britain is that oats are not always replaced by another grain. The decline in the price of oats seemingly makes it more profitable to grow more grass; the discontinuing of oats production means discontinuance of grain production. This tendency might have been in evidence, it is true, even without the decline in oats prices, but would probably have been less strong otherwise.

World production in the past.—The not very comprehensive data on "world" production in the approximately 30 years prior to the World War¹ indicate an increase in oats production in that period greater than in any other grain here studied. The large oats acreages in areas where average yields were enlarged greatly over the period were mainly responsible for this phenomenon. It may nevertheless also be regarded as sufficient proof of the considerable ability of oats to adjust themselves to the modern technique of crop production, which made large headway in those years.

The same ability, and even more the difficulty of replacing oats by some other crop in regions where they are grown is still more strongly evidenced by postwar developments asso-

¹ For sources, see footnote 29, p. 496.

ciated with the great progress of motorization both of transport on the road and of farm field work. In the United States, in spite of the practical disappearance of nonfarm horses and a reduction of horses and mules on farms since 1913 by about 40 per cent, production of oats declined only 18 per cent from 1909-13 to 1933-37. (The decline would have been even less had not the crop of 1935 been severely reduced by drought.) The reduction of oats production in the United States in postwar years has been more than offset by increases in some other countries, and total world production of oats has even risen by approximately 5 per cent since the latest prewar years.

WORLD TRADE

Although the important deficit regions are among those with moister climates and oats rank high in the grain production of these regions, there was, and in fact still is, relatively much room for domestic trade in this grain. Farmers of deficit regions seldom sell any feed and many of them buy substantial quantities. They are particularly disinclined to part with their oats, which supplement well the roughage produced on their farms for dairy and other livestock. Before the motorization of road transport, cities and towns were heavy buyers of oats. The armies at that time also needed large quantities. As recently as 1927-29, approximately the same percentage of the oats crop was shipped out of the county where grown in the United States as that of corn harvested for grain.

Before the World War, there was a relatively large trade in oats even in the international market, although importing countries themselves produced large quantities of oats, and international trade in oats was hampered by the disproportionately high cost of ocean transport and of elevator handling of this grain. But oats were considerably behind corn and barley in the quantity traded internationally. As shown in Table V, world net exports of oats were little more than one-

third of those of corn and little more than two-fifths of those of barley, in the five years ending in 1913-14.⁸ Still, the trend in net imports of oats was definitely upward in prewar years.

The situation changed fundamentally after the World War. Motorization of road transport, including that of field artillery and cavalry, made great progress in those European countries which had been heavy importers of oats in prewar years. Motorization of farm field work, although not yet a big factor in western Europe, advanced most in Great Britain, by far the largest prewar importer of oats. In the years preceding the recent big depression, net imports of oats were only slightly more than half their prewar size. Even Argentina, despite her ability to export cheaply, could not keep her oats exports up to the prewar level. In recent years, world net exports of oats have averaged less than a million metric tons annually. Net imports of the United Kingdom have dwindled almost to insignificance.⁹ Little Switzerland, with practically no grain production of its own, now tops all other importing countries with net imports averaging less than 200,000 tons in 1935-37.

OUTLOOK

A horse of today is the same as that of ten years ago, and will hardly show any difference ten years hence; but the automobile, truck, bus, road and farm tractor are much better in quality than they were in 1929, and they are likely to undergo further important improvements in the next ten years. Doubts can be entertained only with regard to the speed with which road transport and farm field work will continue to be motorized.

⁸ Moreover, oats exports were not particularly profitable. Only Russia and Argentina were heavy exporters. Russia was a backward country where adjustments to market conditions were proceeding very slowly. A large portion of the Russian oats used the short route through the ports of the Baltic Sea (Petrograd, Tallinn, Riga, Libau) and was therefore little handicapped by the high ocean freight rates on oats. Argentine oats are partly a by-product of the cattle industry (see p. 490).

⁹ Their net imports in 1935-37 averaged 115,000 metric tons as against an average of 896,000 tons in 1909-13.

With the continuing loss of the best customers for oats, there is little likelihood that world production of this grain can be kept at its present level. The tendency of the price of oats to be the least satisfactory among all grains, save perhaps rye, may be expected to continue for many years to come. Oats will tend to be increasingly restricted to growing conditions where they are indispensable owing to poor soil, especially acid soil, excessive precipitation, or rotational requirements. But the proportion of very acid soils on which it is difficult to find a substitute for oats is persistently being contracted, though very slowly, by the increasing use of lime. The climate of course cannot be changed, but in areas with very heavy precipitation producers may find it advisable to continue diminishing their acreage in oats and all grains in favor of grass. Still, the large advantages that oats command in production will make the decline in their production a very slow process, especially owing to the fact that oats are grown primarily in regions of increasing fertility and rising yields. In fact, should total world production of grains here studied show a more or less strong upward trend, the decline in oats production may be merely a relative one.

Trade, and international trade in particular, is likely to remain at the present low levels or proceed in its declining phase.

APPENDIX NOTES

NOTE A

MARKETING COSTS

To supplement the brief discussion of costs involved in marketing grain on pages 140-49, it seems appropriate to give some additional detail on the major operations involved—transportation by rail and by water, and handling charges; but comprehensive treatment is neither needed nor attempted.

RAILWAY TRANSPORTATION

Railways, more or less monopolistic institutions with fixed costs a very high proportion of total costs, habitually make their rates dependent not only on such factors as volume and weight of the goods, which affect the cost of transportation to the railway, but also upon what charges the goods can bear. Thus, in the case of grains we have two principles in part contradictory. The principle of cost to the railway would involve charging the same rate—per unit of weight—on all heavy grains, slightly more on barley, and even more on oats (see p. 141). The principle of charging according to what the goods can bear, on the other hand, would call for placing the highest charge on wheat. The practice is usually to charge all grains the same rate.¹ Frequently this rate applies also to flour. In the apparently infrequent exceptions, wheat is usually charged a somewhat higher rate. However, when competition with water transportation compels railways to lower their rates to approximately the differential costs,² they sometimes refuse to reduce the rates on barley and oats to that on wheat.

In the United States, rates on coarse grains vary from 0 to 10 per cent less than the rate on wheat. The important all-rail domestic and export reshipping rates to Atlantic ports are either equal on all grains or (from Minneapolis and Kansas City) the rate on corn is 1.5 cents per 100 pounds (equivalent to 2 to 5 per cent) less than on wheat. The rates ex-Lakes to Atlantic ports for export on corn and rye are slightly less than those on wheat, while the rates on barley and oats are 12 and 10 per cent higher than the wheat rate.³

¹“From a transportation standpoint there is no justification for rates on coarse grains . . . lower than on wheat. Coarse grains load lighter than wheat. Perhaps the main argument in favor of the differential is the somewhat lower value. Substantial justice can best be done to shippers of both wheat and coarse grains by one rate on both classes of traffic.” Interstate Commerce Commission, No. 17000, *Rate Structure Investigation, Part VII. Grain and Grain Products within Western District and for Export*. Submitted July 1, 1929, decided July 1, 1930, p. 652.

²I.e., the difference between the costs which would be incurred if the goods in question were hauled and those which would be incurred if they were not hauled.

³U.S. War Department, Corps of Engineers, U.S. Army, *Transportation on the Great Lakes*, prepared by Board of Engineers for Rivers and Harbors (Transportation Series No. 1, revised 1937), pp. 194-95.

With some exceptions, railway rates in Canada are the same for all grains. The more important exception is that the rates ex-Lakes, Bay ports to Montreal and Canadian Atlantic ports are arranged in the same way as in the United States; rates on rye and corn are slightly less than on wheat, while oats and barley are charged more than wheat by nearly 10 and 13 per cent, respectively.

In Argentina the freight rates on corn and barley were 15 to 20 per cent less than on wheat, rye, and oats in 1938.⁴ As to other countries, we have found that in Great Britain, Germany, Belgium, Switzerland, and Bulgaria the rates on all grains are the same. This was also the situation in prewar Russia. As regards France, our information is that the rates are the same for wheat and barley, but 20 per cent higher for rye.

Since railway tariffs in general are fixed more or less arbitrarily, several other deviations from the principle of proportionality between costs to the railway and rates charged to the shipper are in vogue. Two are important for our discussion. Railways of many countries make it their practice to charge high per-mile rates for short hauls, while reducing disproportionately the rates for long distances. The larger a country, the further its railways usually go in this practice. The rate from Calgary, Alberta, to Fort William-Port Arthur is only 36.3 per cent higher than from Indian Head, Saskatchewan, to the same destination, although the distance is 77 per cent longer. Likewise, the distance from Goderich, a Georgian Bay port, to Montreal is only slightly more than one-third that to St. John, New Brunswick, but the rate is only 4 per cent less. The second peculiarity which should be mentioned here is that railways frequently charge more for shipments destined for domestic consumption than for those destined for export. Not infrequently the difference is rather large. The rate on grain and grain products from Indian Head, Saskatchewan, to Vancouver, B.C., for example, is 52½ cents per cental for local delivery and only 27 cents for export.

OCEAN TRANSPORTATION⁵

Practices in water transportation differ materially from those predominant in railway transportation. Shipping is much more competitive; especially in tramp shipping, ownership is widely split, many vessels being individually owned. Furthermore, a large amount of goods is shipped either in full cargoes, i.e., in vessels chartered by one shipper mostly for one type of goods, or in vessels chartered by more than one shipper but for the same type of goods. Under these conditions each

⁴ Information from Comisión Nacional de Granos y Elevadores, Buenos Aires, as of May 1, 1938.

⁵ The writer is indebted to Mr. G. Schwob of the firm of Louis Dreyfus & Cie. (Paris, France) for reading a draft of this subsection and making valuable suggestions. For details on ocean transportation of grain and freight rates see V. D. Wickizer, "Shipping and Freight Rates in the Overseas Grain Trade," *Wheat Studies*, October 1938, XV, 49-120.

cargo has to pay shipping costs in full, the principle of varying the charge to the shipper according to what the goods can bear being applicable mainly to mixed cargoes shipped in liners. To a very large extent, grain is shipped in full cargoes or in any case in vessels carrying nothing else.

The volume of the cargo (in cubic feet or in cubic meters) is even more important for the cost to the shipowner than is true of the cost to the railway. Shipowners even show an inclination to make the freight rate proportionate to the bulkiness of the grain. They sometimes succeed, though such demands are not justified by the present stage of shipbuilding. A vessel cannot take more cargo than its deadweight, even when there is space left in the holds. When the deadweight is reached, the shipowner has no further interest in the bulk of the cargo, i.e., in the case of grain, in its test weight, except that it takes more time to load and unload lighter grain. The ship may also sometimes have to bear a higher expense for loading and unloading the lighter grain.⁶

According to Macmurray and Cree,⁷ grains stow approximately as follows, in cubic feet of space per long ton of weight:

Wheat	47	Rye	48-50
Wheat in bags.....	53	Barley	58-60
Maize	45-50	Oats	65-70

An experienced grain shipper⁸ regards the following figures as preferable: wheat in bags 51, oats 70, clipped oats 62, and barley 55. Thus wheat in bulk requires the least space, with corn about the same. Oats of course are the bulkiest, with clipped oats somewhat less bulky than unclipped. If the deadweight is not reached by a cargo which stows more than 45-47 cubic feet to the long ton, the shipowner is justified in asking for any grain other than wheat a rate that is higher than that for the latter in inverse proportion to their test weights. But ships with so low a stowing capacity are rare nowadays. Most modern ocean vessels can load a full cargo of goods which stow 60 cubic feet to the long ton and more, and many vessels can reach deadweight by loading grain which stows 55 cubic feet to the long ton.⁹ This makes baseless requests for higher rates on any grain other than oats and sometimes barley, except as justified by higher cost of and delay in loading and unloading, if any.

The 1890 Black Sea Charter Party and similar charters for shipment

⁶ Most international charter parties stipulate that the charterer must deliver and receive the grains alongside the ship, i.e., the actual loading into and unloading from the holds of the ship have to be done by the shipowner.

⁷ C. D. Macmurray and M. M. Cree, *Shipping and Shipbroking* (3d ed., London, 1934), p. 90.

⁸ Mr. G. Schwob, cited above.

⁹ According to C. D. Macmurray and M. M. Cree (*op. cit.*, p. 84), some vessels have only sufficient cubic space to stow up to their deadweight cargo measuring about 50 cubic feet to the long ton, while others may stow cargo up to 60 cubic feet and 70 cubic feet.

of grain from the Azov Sea and from the Danube¹⁰ provide that payment must be agreed upon per rate unit equivalent to a long ton of 2,240 pounds. For different grains, the unit equivalents are, in pounds:

Wheat and corn	2,240	Barley	2,050
Rye	2,220	Oats	1,600

Thus corn is transported at the same rate as wheat, and only 1 per cent more must be paid for rye. The additional payment for barley amounts to 9.3 per cent or less than half of what should be paid if rates were proportional to the bulkiness, and this surcharge is generally reduced further by stipulating a discount of 3 pence per unit ton. Oats have to pay a surcharge of about 40 per cent, but this is only about half of the surcharge that would have to be paid if the rates were proportionate to the test weight.

In 1912 another charter was added for shipments from the Black Sea (*Black Sea Berth Contract, 1912*, code name, "Russcon"). Under this contract charterers have the option of shipping a full and complete cargo of wheat and/or grain and/or other lawful merchandise on a *deadweight basis*. With the present capacity of ships to stow cargo, the deadweight basis is more favorable for shipment of light grain than the rates provided by the 1890 charters.

The deadweight basis for light grain is also accepted by the *Chamber of Shipping River Plate Charter Party, 1914, Homewards* (code name, "Centrocon"), which stipulates the shipment of wheat and/or maize and/or rye at so much per long ton. "Charters have the option of shipping other lawful merchandise, . . . in which case freight to be paid on Steamer's dead-weight capacity for Wheat in bags on this voyage at the rate . . . agreed on for heavy grain . . . but Steamer not to earn more freight than she would if loaded with a full cargo of wheat in bags." Thus the contract excludes any additional charge for rye (in addition to corn that earlier had been put on the same footing with wheat), and enables the shipper to have the still lighter grains carried on a *deadweight basis*.

The rather heavy California barley is carried at the same rate as wheat. The San Francisco form of charter party stipulates that the vessel must load wheat and/or barley at so much per 2,240 pounds. The interests of the shipowners, it is true, are protected by the usual stipulation that the master can require a full cargo. So far as other barleys are concerned, an additional charge is hardly ever involved when barley is shipped together with some heavier grain in tramp ships chartered for full cargoes, while it may still be necessary to pay an additional charge for lighter barleys shipped in full cargoes or as parcels.

So far as we have been able to ascertain, the rates on barley shipped

¹⁰ Standard charters adopted by the Chamber of Shipping of the United Kingdom and predominantly used in international shipping.

in parcels are materially higher than on parcels of heavy grain only when the barley is shipped from Atlantic ports and payment is agreed in sterling. Our information indicates that in these cases the usual rate is 2 pence less per quarter of 400 pounds of barley than per quarter of 480 pounds of wheat. At rates of 3s. per quarter of wheat and 2s. 10d. per quarter of barley, the rate per cental is 13 per cent higher on barley than on wheat. However, when the freight on parcels from the Atlantic ports is agreed upon in American cents per cental (a basis common for shipments to the European continent), the usual freight is 1 cent higher on barley than on wheat, although some lines charge 2 cents more. At a rate of 15 cents per 100 pounds of wheat, 1 cent more is equivalent to an additional charge of 7 per cent.

A small parcel of oats can be added to an almost full cargo of wheat or other heavy grain and the rate for oats will be the same. But, on the whole, ocean transportation of oats still costs materially more than transport of heavy grains. According to our information, the usual rate in parcels from Argentina is $7\frac{1}{2}$ per cent higher on oats than on wheat (5 per cent higher on clipped oats);¹¹ with the usual discount of 4 pence per quarter of 320 pounds of oats from the rate per quarter of 480 pounds of wheat on parcel shipments from Atlantic ports, the charge per cental is about 33 per cent higher on oats than on wheat.¹²

TRANSPORTATION ON INTERIOR WATERWAYS

The situation in river transportation is again somewhat different from that in ocean transportation. There are frequently rigid limitations as to the draft of the vessel. The ratio between the weight of the craft and its capacity tonnage is less than that in ocean vessels, and the price of the craft per ton of capacity is much less. All these factors tend to reduce the effect of bulkiness of the grains on the cost of river transportation to the shipowner and on the freights he has to charge. Not infrequently, even oats can be transported at no higher cost than wheat.

Transportation on lakes and interior seas stands between transportation on the ocean and on rivers. The situation approaches the one or the other more or less, depending on the calm and the depth of the waters involved. Water requiring ships resembling those used on oceans calls for rates similar to those in vogue in ocean transportation, and vice versa.

Differences in conditions of navigation, however, do not alone determine the rate-structure on interior waterways. At first thought, it seems to be unlikely that so seemingly indifferent a matter as identity or difference in the weight-unit for all grains could have an effect on marketing costs. Yet even in ocean transportation we saw that differentials are not the same in shipments from the same countries (Atlantic

¹¹ This information, though obtained from an excellent source, we give with some reserve.

¹² When the rate is agreed upon in American cents per cental, the usual rate on oats is 2 cents higher than on heavy grain, although some lines charge 4 cents more.

ports), depending on whether the freight on each specific grain is agreed upon per quarter of different weights or per cental. As from ocean routes subject to international competition and frequently to international regulation, we enter national territories, the weight-unit becomes even more significant. Study of the rates in use on rivers and interior waterways persuades one that the attitudes toward lighter grains in countries with equal and with different weight units differ greatly; and even more striking are results obtained from study of handling and storage charges in the next section.

The navigation conditions on the Great Lakes—the world's most important interior waterway for grain—are similar to those prevailing in transportation on the ocean; but the differentials against the lighter grains are much larger. The writer is obliged to Dr. E. A. Ursell, Statistician of the Board of Grain Commissioners for Canada, for the following examples of rates from Fort William—Port Arthur to indicated points:

Grain	Montreal, Sorel, or Quebec		Georgian Bay ports		Buffalo
	(Cents per legal bushel)				
Wheat and rye.....	6	5	2 $\frac{1}{4}$	2	2 $\frac{1}{4}$
Barley	5 $\frac{1}{2}$	4 $\frac{1}{2}$	2	1 $\frac{3}{4}$	2
Oats	4 $\frac{1}{4}$	3 $\frac{3}{4}$	1 $\frac{3}{4}$	1 $\frac{1}{2}$	1 $\frac{3}{4}$
(Cents per cental)					
Wheat	10.00	8.33	3.75	3.33	3.75
Rye	10.71	8.93	4.02	3.57	4.02
Barley	11.46	9.38	4.17	3.65	4.17
Oats	12.50	11.03	5.15	4.41	5.15

Thus rye must pay more than wheat in exact proportion to the difference in the weights of the respective bushels. Barley is charged 10–15 per cent more than wheat, and oats 25 to nearly 40 per cent more. In *Transportation on the Great Lakes*, the following rates from Port Colborne to Montreal are presented, in cents per cental:¹³

1928	Wheat	Barley	Oats
May	11.23	12.06	14.74
July	8.40	7.29	10.65
August	8.40	10.10	10.79
September	9.67	10.73	10.41
Average	9.43	10.04	11.65
1935	Wheat	Barley	Oats
June	4.27	4.98	5.79
October	4.50	5.00	6.68
November	4.40	4.29	6.26

¹³ Rates for 1928 from the revised edition of 1930, p. 159; rates for 1935 from the revised edition of 1937, p. 193.

These rates yield approximately the same ratios between the rates of different grains as those from Fort William-Port Arthur to Montreal, Sorel, or Quebec.

The large differentials against the lighter grains on the Great Lakes may be partly explained by the short distance, particularly to Buffalo or Georgian Bay ports, for the additional time required for loading and unloading the lighter grains plays a greater role in short than in long hauls. It is, however, much more important that the vessel must bear several expenses which are the same per bushel of different grains. The small amounts of coarse grain shipped may also be a factor, especially in the case of rye. But the bushel of different weights legally accepted in the United States and Canada as the trade unit undoubtedly has much to do with these differentials even aside from its effect on the above-mentioned expenses of the shipowners.¹⁴

To how large an extent the bushel of different weights as the trade unit affects the rates in interior waterways is evident from the fact that per-bushel rates in the New York State Barge Canal are almost equal on all grains, i.e., they are higher on lighter grains almost in proportion to the difference in the bushel weights. We are indebted to the Board of Engineers for Rivers and Harbors, U.S. War Department, Washington, D.C., for the following rates charged on the Canal in 1936, but verifiably typical, in cents per bushel of legal weight:

1936	Wheat	Corn	Rye	Barley	Oats
Opening of season to June 1.....	3	3	3	3	2½
June 29 to July 25.....	1¼	1¼	1¼	1¼	1
July 27 to August 22.....	1½	1½	1½	1½	1
August 24 to September 12.....	¾	¾	¾	¾	¾
October 19 to October 24.....	3	3	3½	3½	2½
November 2 to close of navigation..	3½	3½	3½	3½	3¼

Thus, barley is quite regularly charged exactly the same rate per bushel as wheat, or 25 per cent more than wheat on an equal-weight basis. The per-bushel rate on oats differs so little from that on wheat that the charge on oats per unit of weight is some 50 per cent higher than on wheat. The large additional charges on barley and oats on a weight basis on the New York State Barge Canal are the more striking, since the water route competes with railways which charge per cental of light grain only 12 per cent (barley) and 10 per cent (oats) more than for the same amount of wheat.

The Federal Barge Lines operating on the Mississippi charge in general the same ton-mile rates for all grains, probably partly because they

¹⁴ This effect is particularly evident when the amount of light grain shipped or handled is small and there is no reason to bother to set a special rate. In this case the rate in countries adhering to the bushel is the same per bushel of different weights, while with an equal weight unit it is equal for equal weights.

are a federal institution and partly because the charge is per ton, a weight-unit equal for all grains.

HANDLING AND STORAGE CHARGES¹⁵

The effect of the trade unit is particularly apparent in charges for handling and frequently for storage as well. In Canada, for example, where the whole country uses the bushel of different weights, an equal per-bushel charge for manipulation and storage of all grains is the rule. It is charged even for such an operation as drying, although to extract a given percentage of water from a bushel of wheat requires much more heat, time, and cost than to extract it from a bushel of oats. Exceptions from the equal per-bushel rate are rare; the principal ones are a higher elevation charge per bushel on rye at many elevators, lower per-bushel rates on oats at country elevators, and a much lower elevation charge on wheat at interior elevators.¹⁶

The equal per-bushel charge on all grains is also the rule in the United States east of the Rocky Mountains. For example, the rate of $1\frac{1}{4}$ cents per bushel for receiving and shipping, including ten days of storage and insurance, with $\frac{1}{20}$ cent for each additional day of storage, is widely used by terminal elevators in the interior and in ports. All other operations are also charged on the equal per-bushel basis.¹⁷ Exceptions seem to be rare. One of them is Indianapolis, where for transferring oats they charge $\frac{1}{2}$ cent per bushel as against $\frac{3}{4}$ cent on all other grains; but all other rates are on the per-bushel basis and equal. Again, even the rate for drying is usually on the equal per-bushel basis in the eastern United States.

The rate structure becomes materially different when we traverse the Rocky Mountains and enter the regions where the cental or the ton is the unit and not the weight unit called the bushel. At the Pacific ports, charges for all grains are uniformly on the basis of a ton of 2,000 pounds. With the exception of the rates on barley and oats and the storage rate on corn, the rates are the same per ton of all grains at Portland, Oregon,¹⁸ and Seattle, Washington.¹⁹ The rates on oats and barley, so far as they are not specifically provided for, are higher than those on other grains by 25 and 10 per cent, respectively. For operations specifically provided for, the percentages by which the rates on barley and oats are higher than

¹⁵ Handling charges include such operations as loading, unloading, trimming, sacking, cleaning, drying, and the like. They do not include charges for transportation, storage, interest, insurance, and the remuneration of the middlemen.

¹⁶ Maximum charges as prescribed by the Board of Grain Commissioners of Canada in all cases. Published in *Transportation on the Great Lakes*, p. 197.

¹⁷ See, for example, the rate in Baltimore in U.S. War Department, Corps of Engineers, U.S. Army, *Port and Terminal Charges at United States Ports*, prepared by Board of Engineers for Rivers and Harbors (Misc. Series No. 1, 1938 ed.), p. 59.

¹⁸ *Grain Tariff No. 1-A* (Commission of Public Docks, Portland, Oregon), effective July 1, 1937.

¹⁹ *Port and Terminal Charges at United States Ports*, p. 681.

on heavy grains are partly the same as stated and partly less (the rate for handling of sacked oats, for example). The only exception is the storage rate on oats (1 cent per day as against 10 cents per month for all other grains except corn), which probably is set at this relatively high level²⁰ in order to discourage storage of this grain occasionally available in small quantities only. The same consideration is probably the reason for fixing the per-ton rate on storage of corn considerably higher than on other grains except oats.²¹

So far as units of measurement of grains are concerned, Great Britain is in an intermediate position. Along with quarters of different weights, the hundredweight of 112 pounds also is much used in the grain trade. Moreover, international influences which include those of the metric system are felt much more strongly than in North America. These mixed influences are clearly reflected in the rates charged at Liverpool. Several operations there, including cooling and drying, are strictly on a per-ton basis. The same pertains to rent of storage space, so far as the grain is stored in original sacks, and to the operation *ex-cart*. But the charges for the most important operation *ex-ship, in bulk* are higher for lighter grains, the additional charges for barley and oats being 15 and 34 per cent, respectively; the differentials on warehousing of this grain are even larger.

The situation is still more favorable for coarse grains within the domain of the metric system. At Antwerp, all handling charges (as established by the Syndicat des Corporations et Entrepreneurs de Transport et Manipulation de Merchandises au Port d'Anvers) are per 100 kilograms for all grains except oats, for which the rates are higher by .20 francs per 100 kilograms. For typical operations this increase is equivalent to 10 to 25 per cent. The Société Anonyme des Magasins à Grains d'Anvers charges 20 per cent more on oats than on other grains for all operations except storage, which is charged on a volume basis.

At Genoa, Italy, the elevators charge for all operations, including storage, 10 per cent more for barley and rye and 20 per cent more for oats than for the other grains.

At Hamburg, the principal port of Germany, floating elevators charge a uniform rate per metric ton of 1.30 Reichsmarks plus 8 per cent, plus per elevator 70 Reichsmarks for towage. Only this last charge may be slightly larger per ton of a lighter grain, since the total amounts of grain for which an elevator is requested may average less. Stationary elevators in German ports treat all grains except oats as heavy grain that is charged the same rate per ton, and oats, the light grain, are frequently not

²⁰ One cent per ton per day on oats is less than half of the rate prevailing for this grain in the East.

²¹ In San Francisco the rates per short ton are the same on all grains, not excepting oats. The reason may be that too little oats is handled to warrant establishing special rates for this grain. If under the same circumstances the per-bushel rates were applied, oats would be charged nearly twice as much as wheat.

charged a higher rate per ton. So far as surcharges are provided for oats, the light grain, they do not exceed 20 per cent of the base charge, and are frequently less.

As to Danzig,²² the unusual fact is worth mentioning that discharge of grain in bulk ex-steamer into store, inclusive of 30 days uninsured free storage and of delivery free wagon or river ship, is lower on rye than on wheat—4.08 Polish zlotys as against 4.25; but the rate on barley and corn is 4.50 zlotys. Unfortunately, we do not know the rate on oats.²³

In Argentina²⁴ handling at country railway stations is charged per bag. The charge is equal on all grains but the weight of a bag of oats is about 10 per cent less than those of the other grains. Storage space is charged per square meter. Some port elevators charge for handling barley and oats in bulk 20 per cent more than the basic rates (30 per cent more for storage); but the elevator del Ferrocarril Central Argentino in Buenos Aires and the elevator del Ferrocarril del Sud in Bahía Blanca (a very important port for coarse grains other than corn) apparently charge the same rates on all grains. The charge for transfer from railway cars to alongside the ship without the use of elevators is the same on all grains either per 100 kilograms or per sack of a certain weight. But the total transfer costs to the shipper that include taxes are smallest on corn and largest on oats, barley, and rye. The Southern Railway, for example, charges for the transfer from railway cars to alongside the ship 13 centavos per 100 kilograms, but the total transfer costs are 30 centavos for corn, 45 centavos for other coarse grains, and 35 centavos for wheat.

²² Not a German port at the time of writing.

²³ H. Siepmann of the Controlli-Co. MBH. Hamburg, branch house of the Société Général de Surveillance, Geneva, Switzerland, kindly supplied the writer with information on the rates charged in many German ports and in Danzig. The information on Antwerp and Genoa was provided by F. van Brée, S.A., Antwerp, and Sorveglianza, Genoa, branch houses of the same company. The writer is much indebted to them.

²⁴ Information of Paul O. Nyhus, Agricultural Attaché, Bureau of Agricultural Economics, U.S. Dept. of Agriculture, and of Comisión Nacional de Granos y Elevadores.

NOTE B

DATA ON ACREAGE AND YIELDS IN A SECTION OF THE UNITED STATES

Data on acreages and yields in the states of North Dakota south to Oklahoma and Minnesota south to Missouri (some of them in part) are repeatedly used in this study (e.g., in Charts 43 to 45 and Tables 10 and 12). In order to reduce the amount of work, and yet to have data with local differences originating partly from inaccuracies of statistics smoothed, it was decided to use data by crop-reporting districts. These were kindly supplied by the officials of the U.S. Department of Agriculture in charge of statistics in each state.

The comparison of yields of course had to be made on the basis of averages for a number of years that are both up to date and representative. Unfortunately it was impossible to comply simultaneously with both requirements, particularly since very extensive clerical work could not be undertaken. First of all the recent exceptional drought period had to be excluded. Except where specifically pointed out, no data were used extending later than 1932. Mostly 10-year averages were used; yet, although we are interested merely in ratios between yields rather than in yields themselves, 10-year averages seem to afford an insufficient safeguard against spurious influences. The data appear to be imperfect, particularly with regard to the comparability of yields of corn with those of the small grains, owing to differences in the growing seasons. The table below, showing the state yield ratios for the periods used—these are the most recent periods shown in the table for each state except South Dakota—as well as for one or two preceding similar periods, enables one to form an idea regarding representative character of the ratios used.

As may be observed from the table on page 558, in North Dakota and Minnesota, wheat yields expressed as percentages of corn yields showed a dip in the 1920's but recovered the losses within the period used for our charts; the use of 30-year averages rather than averages of the most recent 10-year periods would not yield substantially different results.

The yields of corn in Iowa, Kansas, Nebraska, Missouri, and Oklahoma have persistently declined relative to those of wheat. In Iowa this relative improvement of wheat yield may have resulted from recent contraction of the wheat acreage. In some of the other states it might have been caused by expansion of corn acreage into drier portions. In any case, we do not hesitate to use the data for the last period shown in the table, in the belief that the broad conclusions drawn from them will not be vitiated by the insufficient representativeness, if any, of the data.

We have been, however, greatly at a loss with regard to the South Dakota data. There were at hand average yields by crop-reporting districts in 1924-35. Comparison of the state data in this period with those in two preceding periods (see table, p. 558) leaves no doubt that they

COMPETITION AMONG GRAINS

 YIELDS OF SMALL GRAINS IN PERCENTAGES OF CORN YIELDS IN STATES
 AND PERIODS SPECIFIED*

	1902-11	1912-21	1922-31		1903-12	1913-22	1923-32
North Dakota				Oklahoma			
Wheat.....	61.3	48.8	61.9	Wheat.....	55.7	76.3	80.6
Rye.....	59.5	51.7	58.7	Rye.....	37.8	48.8	53.5
Barley.....	77.2	68.6	80.5	Barley.....	54.1	71.1	80.5
Oats.....	71.8	63.7	67.2	Oats.....	61.2	73.3	71.6
	1904-15	1916-27	1924-35		1903-12	1913-22	1923-32
South Dakota				Minnesota			
Wheat.....	50.3	47.1	65.1	Wheat.....	49.1	42.2	50.5
Rye.....	55.1	53.0	70.8	Rye.....	51.0	47.0	49.7
Barley.....	73.6	68.4	95.5	Barley.....	64.2	60.8	69.3
Oats.....	65.0	66.3	86.1	Oats.....	54.2	56.1	62.4
	1903-12	1913-22	1923-32		1900-09	1910-19	1920-29
Nebraska				Iowa			
Wheat.....	64.9	66.1	68.8	Wheat.....	42.3	50.1	51.2
Rye.....	38.0	39.0	41.7	Rye.....	41.0	38.1	40.3
Barley.....	54.7	64.2	76.4	Barley.....	56.8	59.0	60.3
Oats.....	51.0	65.3	64.1	Oats.....	46.0	54.6	50.3
	.....	1889-1910	1911-32		1902-11	1912-21	1922-31
Kansas				Missouri			
Wheat.....	.....	66.4	79.2	Wheat.....	49.5	56.0	58.3
Rye.....	.....	49.6	59.4	Rye.....	33.1	34.4	38.0
Barley.....	.....	57.6	71.3	Barley.....	46.1	58.2	64.4
Oats.....	.....	60.8	74.3	Oats.....	38.8	51.3	47.3

* Official data. Percentages were computed after the yields were converted from bushels to a uniform basis.

cannot be considered representative. The same conclusion is indicated by an analysis of the distribution of acreages between different grains. If included in Charts 43 and 45, the ratios between the yields of 1924-35 would simply fall out of the picture.¹

An alternative to using South Dakota data by crop-reporting districts for 1924-35 was to use yields by type-of-farming areas in "normal" years given in *Types of Farming in South Dakota*.² These are median yields in 1916-27. But while the 1924-35 data misrepresent the situation in disfavor of corn, those of 1916-27 seem to favor it unduly. The way out of this difficulty was to adjust either the data of 1924-35 or those of 1916-27. The adjustment could have been made only on the basis of the *state averages*, although the conditions of 1924-35 particularly unfavorable to corn and conditions of 1916-27 particularly favorable to it may have

¹ The difficulty arises mainly with regard to comparisons of the yield of corn and wheat. Data for small grains, the growing period of which largely coincides, do not reveal such discrepancies. Hence data of 1924-35 have been used in Tables 10 and 12.

² South Dakota Agr. Exp. Sta. Bull. 238, June 1929, by R. H. Rogers and F. F. Elliott.

diminished and raised the relative yields of corn in different sections of the state in different degrees. Since there was no way to find out which was more satisfactory, the 1916-27 yields of corn in each type-of-farming area have been reduced by half of the difference between the average state yields in 1916-27 and 1924-35. The average yields of corn in 1924-35 in each crop-reporting district were similarly adjusted. The adjusted median values of 1916-27 were used in Chart 43 and the adjusted yields of 1924-35 in Chart 45.

Data on acreages used in Chart 44 are for the same years as those on yields in Chart 43, except for Iowa and Kansas, for which the data of the census 1929 were used. For South Dakota, the acreages used are averages of 1924-35. All acreages are those harvested for grain, except that corn acreage includes corn for all purposes.

COMPUTATION OF COSTS OF CROPS PRODUCED IN ROTATION¹

Some fifteen to twenty-five years ago, costs of production of individual crops computed by the accounting method were very popular in North America and were assembled by many agencies. They have, however, fallen into disfavor.² The principal reason was that they were expected to satisfy needs which could not be satisfied. It was claimed without qualification that the data as arrived at by accounting could serve both to guide farmers as to what to grow, and for use by the government and general public for such purposes as price fixing, tariff legislation, and the establishment of fair railway tariffs.³ The use by the government and general public, for which the accounting data in their original form were least adequate, has indeed always been in the foreground.⁴

Moreover, these unwarranted expectations were cherished in spite of the extremely primitive form in which farm accounting has been conducted. Large amounts of money were available for factual studies with the use of the crude methods then (and now) in vogue, but relatively little attention was devoted to improving the methods and to determining more precisely what uses the data might serve successfully. Failure of the data to do what was claimed for them caused collection to be dis-

¹ Thanks are due to Dr. M. R. Benedict, University of California, and Dr. J. D. Black, Harvard University, for criticism of earlier drafts of this note. As is true of the whole study, the writer is solely responsible for statements made.

The official report on *Production Costs and Returns* by M. R. Cooper (U.S. Dept. Agr., mimeographed publication, April 1939) unfortunately came too late to the attention of the writer to be considered here.

² M. K. Bennett, *Farm Cost Studies in the United States* (Food Research Institute, Miscellaneous Pub. 4, Stanford University, Calif., 1928); J. D. Black, *Introduction to Production Economics* (New York, 1926), chap. viii; J. D. Black, "Unit Cost of Production of Farm Products," *Research in Farm Management. Scope and Method* (Social Science Research Council Bull. 13, June 1932), pp. 262-71; M. R. Benedict, "The Opportunity Cost Basis of the Substitution Method in Farm Management," *Journal of Farm Economics*, July 1932, XIV, 384-405; *ibid.*, October 1932, XIV, 541-57.

European students passed through the phases of enthusiasm and disappointment much earlier. Fr. Aereboe published his fiery attack on cost-of-production computations (*Landwirtschaftliche Rentabilitätsfragen*, Berlin, 1901) when they were only starting in North America. For more recent presentations of the views of Aereboe's school, see Hans Zörner, "Untersuchungen über die Bedeutung von Kalkulationen und Produktionskostenrechnungen in der Landwirtschaft," *Berichte über Landwirtschaft*, 1927, VI, 554 ff. The views of those in favor of the cost-of-production computations are represented by E. Laur, *Grundlagen und Methoden der Bewertung, Buchhaltung und Kalkulation in der Landwirtschaft* (3d ed., Berlin, 1928).

³ According to G. F. Warren and others, *Cost Accounts for Six Years on Some Successful New York Farms* (Cornell Agr. Exp. Sta. Bull. 414, February 1923), p. 16, for example, the cost accounting recommended by the Cornell Agricultural Experiment Station could provide the necessary information both to the farmer who "desires to know which of his enterprises are the most profitable" and to the public, if it "desired to know whether or not a given price will result in an increased production of a certain product."

⁴ M. K. Bennett, *op. cit.*, pp. 12-28.

continued or greatly curtailed by many agencies. But where collection and analysis are continued, it is done mostly in about the same crude way as was true more than a decade ago.

Certain features of the existing computations of the cost of producing individual crops will be referred to later. Here it suffices to state that the emphasis usually falls on *absolute* cost figures. The reason is that the computed data are commonly intended primarily for use by the government. Farmers' organizations may also be interested in such figures, but the concern of individual farmers is usually with *relative* costs. Ordinarily, the question with them is not whether to leave land unused, but whether to use it for a certain crop or a certain combination of crops in preference to another. In a study of competition among grains we are obviously concerned exclusively with relative costs. Absolute figures have been used only once in the discussion above, and even there no great significance attaches to the conclusions drawn. We make no comparisons of costs of production of the same grains in different regions.

Since absolute cost figures are irrelevant here, discussion of several problems affecting these costs may be avoided. Though their effect is frequently very strong, inaccuracies tend to raise or reduce the costs of all grain crops in the same direction; the *ratios* between the costs may remain unaffected, or such effect may be so small that it can be neglected. On the same reasoning, no space is given to the problems of the costs involved in the growing of crops in monoculture.

The principal difficulties encountered in computations of the costs of individual crops are those brought about by the production of more than one crop (or more than one good) on the same farm, especially if the crops are produced not on separate pieces of land but in rotation. The managerial advantages attained by producing more than one good on the same farm raise the subtle problem of supplementary and/or complementary forms of combined production. The advantages of rotation as a cultural practice make it necessary to deal with a particularly complicated form of supplementary goods, which occasionally for practical purposes cannot be distinguished from joint goods.⁵ All these difficulties have to be faced both by those aiming at absolute figures and by those interested merely in ratios.

JOINT OR SUPPLEMENTARY GOODS

Economic theory usually distinguishes three forms of combined production, of which we are here primarily interested in two: production of joint and of supplementary goods. Joint goods are produced of the same material, by the same labor, and in the same process; supplementary goods are produced in the same plant, with the same overhead cost, sometimes also by the same labor, but of different materials. Joint goods have

⁵ The pure form of joint goods—grain and straw—is also encountered in computations of costs of individual crops, but is mostly of minor importance.

no separate costs.⁶ The cost of each can be determined only arbitrarily, for example, by distributing the cost of all joint products in proportion to their market prices. Much arbitrariness is also involved in computing the costs of supplementary goods. But at least part of the costs of such goods, for example, the cost of raw materials, can be definitely attributed to each. For each of a group of supplementary goods it is possible to compute the cost which would accrue if it were produced alone rather than as a supplementary good. It also has a differential cost, which is equivalent to the difference between (a) the costs of the other supplementary goods as they are produced together with the good in question, and (b) the cost of producing them without the good in question.

Some students are inclined to regard crops produced in rotation as joint goods, and therefore deny the existence of separate costs for them. One reason for this is the specific role of land in the production process. While the factory provides merely the working place, land is both a place and a source of materials, and a source quite different from the usual sources. Moreover, the preceding crop considerably affects the crop or crops which follow it in rotation; and, in the case of rotation including hay, the small grain commonly preceding it plays also the important role of a cover crop. The complementary character of crop and livestock production is a further reason brought forward for classing agricultural products as joint products. The difficulties involved in the appraisal of the usually unsalable manure and unmerchantable types of feeds are specially stressed in this connection.

Yet such crops are hardly joint goods in the strict sense of the term. Not even the grain serving as a cover crop for hay can be considered a joint product with hay. For one small grain and one type of hay can be replaced by another in this combination; there are, if not absolute, then relative individual costs of each small grain and each type of hay.

Crops produced in rotation may therefore be regarded as intermediate between joint and supplementary goods, some rotations approaching the one form of combined production and some the other. For practical purposes, crops produced in some rotations may be considered joint goods. The more specialized the farm business, the more success can be expected from cost-of-production computations; combination of many enterprises has the opposite result.⁷

⁶ See, for example, J. D. Black, *Introduction to Production Economics*, chapter viii. But the line of demarcation between joint and supplementary goods is by no means always distinct. See J. M. Clark, *Studies in the Economics of Overhead Costs* (Chicago, 1923), pp. 98-103.

⁷ The different degrees of combination and specialization prevalent in different regions seem even to affect the judgment of students on the usefulness of cost-of-production computations. The most emphatic opposition to these in the United States comes from the Corn Belt, where the subtle problem of the role of oats as a cover crop plays a very important role. In Europe the most ardent opponents are in Germany with its complicated rotations and great interdependence of crop and animal production, while the cost computations get the greatest support in mountainous Switzerland with its more specialized agriculture.

AVERAGE AND MARGINAL COSTS

Objections to cost computations for individual crops are not limited to the complications introduced by the role of land, the effects of one crop on the yields of another, and the complementary relationship with the livestock enterprises. Objection is also directed toward costs arrived at by the accounting method for any good. The accounting method cannot yield anything but average unit costs. Specifically in the case of crops grown in rotation, accounting does not show that the additional production attained by increasing the proportion of land devoted to a certain crop in the rotation involves costs different from those involved in the production of the preceding quantities. The total unit cost of the additional produce, it is true, may be accepted to be equal to the total unit cost of the preceding quantities, the usually higher unit cost without the charge for land use of the additional produce being offset by the lower charge for land use. But accounting yields equal charges for each item of cost on each unit of the produced good, and such charges can in no case be regarded as correct.

Let us consider, in some detail, unit costs as they are affected by increases in proportions devoted to different crops in rotations, starting from costs excluding the charge for land use.

If a very small portion of a block of land used for the production of crops in rotation is given over to a certain crop, the unit cost of this crop is likely to be high, though it may need operations only during the slack seasons. The waste involved in shifting factors of production to it may more than offset the advantage of low unit costs of these factors. But it can reasonably be assumed that the smallest unit of area in each crop is sufficiently large to make negligible the loss involved in the transfers of production factors from one crop to another. It may also be disregarded, for the moment, that certain minor supplementary crops may require specific machinery, for example, a binder for oats and a mower for hay on a corn farm. With these assumptions, the product produced on the first unit of area will involve the smallest unit cost excluding the charge for land use; for the factors of production are required in the same amounts as for the further increments, but their unit costs are less because at least part of the operations falls into slack seasons. Each subsequent increase in the proportion of acreage devoted to the particular crop raises the unit cost, for the supplies of cheap factors of production are gradually exhausted and ultimately it becomes necessary to use on the crop factors of production at the busiest time and at the highest unit cost. Moreover, while the outlay per acre increases, the yield per acre is likely to decline owing to the inevitable shift of seeding, harvesting, and other operations from the optimum dates and possibly also to the "tiring" of the land of the particular crop.

The increased unit cost without the charge for land use on succeeding portions of the area is offset by diminishing contributions toward the cost of land use. Provided natural and economic conditions are favorable

for the particular crop, it will contribute toward this cost more than a pro-rata per-acre share if it occupies a small proportion of the area. With increase in the proportion of acreage devoted to this crop or crops, the contribution toward the cost of land use gradually declines to an amount less than the pro-rata share. But the increase in the proportion of area in this crop or crops nevertheless continues so long as the contribution toward the cost of land use is not reduced below the amount which could be reaped by devoting a portion of the area to a certain other crop.

Thus if we have two supplementary crops, one of which occupies a large proportion of the acreage and the other a small proportion (but sufficiently large that the unit cost is not adversely affected by the smallness of production), the crop occupying the small acreage need not contribute more toward the cost of land use than the contribution of the last increment or increments of the crop occupying the large acreage, and its cost without the charge for land use may therefore be relatively high. The crop on the large acreage will contribute, for each acre used, more toward the cost of land use than its pro-rata share, but its other costs must be small. The crops occupying large proportions of the acreage will therefore usually represent the *principal* or *leading* crops, while the crops occupying the small acreages will represent the *subsidiary* or *secondary* crops.

Owing to the very marked seasonality in requirements of different crops for factors of production, and to the family character of the farm, farm crops display particularly large variations in unit cost of production excluding land charges, depending on the proportion of the area devoted to them. Many farmers do not look for outside work at a time when they have nothing to do on their own farms; yet leisure has trifling value for many of them. A small acreage of a crop which fits well into rotations with another occupying a large acreage, as for example corn on a wheat farm, may be produced at a very low unit cost (excluding charge for land use) under such circumstances. Moreover, since such a crop usually does not need to contribute a full share of the cost of land use, its total unit cost may also be small—relative to the cost of producing the same crop as a principal one.

The situation can be demonstrated by an example in which corn is the principal crop occupying four fields of a farm and oats are the subsidiary crop grown on two fields. The additional cost and the diminished yield on *all* fields in a certain crop brought about by each increase of the proportion of the area in this crop by one field is charged fully to this field. This accounts for the large increases in per-acre cost excluding the charge for land use, and large declines in acre-yield on successive fields, but the figures are arbitrary at best. As shown in the table on page 565, in our example, the cost per cental of corn, not including the charge for land use, is only 25 cents if one-sixth of the area is in corn, but the extra corn produced by devoting two-thirds rather than half of the area to corn involves a per-cental cost of 55 cents. But the *average* per-

cental cost rises, owing to the increase of the area in corn from one-sixth to two-thirds, to only 36 cents. While the average cost of land use for the whole area is \$5.67 per acre, corn contributes \$10.00 per acre if it is grown on one-sixth of the area; the fourth field, however, if given over to corn, can contribute only \$3.00 for land use, and this makes it profitable to devote two fields to oats.

Crop	Number of field	Yield (centals per acre)	Cost per acre (dollars)			Cost per cental (cents)		
			Without land rent	Land rent	Total	Without land rent	Land rent	Total
Corn.....	1	20	5.00	10.00	15.00	25	50	75
Corn.....	2	18 $\frac{2}{3}$	6.00	8.00	14.00	32	43	75
Corn.....	3	17 $\frac{1}{3}$	7.00	6.00	13.00	40	35	75
Corn.....	4	14 $\frac{2}{3}$	8.00	3.00	11.00	55	20	75
Average ...	1-4	17 $\frac{2}{3}$	6.50	6.75	13.25	36	39	75
Oats.....	5	10	3.50	4.00	7.50	35	40	75
Oats.....	6	9 $\frac{1}{3}$	4.00	3.00	7.00	43	32	75
Average ...	5-6	9 $\frac{2}{3}$	3.75	3.50	7.25	39	36	75

If a certain crop contributes toward the cost of land use \$10.00 per acre when grown on one-sixth of the area, and only \$3.00 on the area in excess of one-half of the total acreage, the knowledge that the average contribution is \$6.75 per acre when two-thirds of the area is in that crop is mostly of little avail. Yet accounting technique thus far has not even reached the stage when the average \$6.75 for the one crop and \$3.50 for the other can be ascertained with anything like precision. The attempts to introduce the principle of marginality into farm accounting have been even less successful.

THE COST AT UNIFORM RATES

Accounting aims at average costs of individual crops as produced on a farm, group of farms, or in a whole country. These costs are henceforth referred to as actual costs. As was shown, in costs including the charge for land use, the unit cost of each additional unit produced by increasing the proportion of the area in a given crop is the same and equals the average or actual cost.

Costs at uniform rates are in general farthest from actual costs. But the costs of individual crops as usually compiled by accounting, although not strictly costs at uniform rates, are commonly close to these. Costs at uniform rates, moreover, frequently have a larger practical value than costs which are slightly closer to actual costs. It seems appropriate, therefore, first to discuss this "pure" form of costs.

Computation of the data.—In computing the cost of production at uniform rates, every crop is charged for the use of all factors of production equal rates per hour, day, or specified operation. This simplifies the procedure, because it is not necessary to inquire whether the crop needs operations at seasonal peaks or at slack seasons, or whether it is more profitable, less profitable, or entirely unprofitable. Great difficulties, nevertheless, are still involved even in computations at uniform rates. The main problems are (1) the distribution of the costs of manure, fertilizer, soil-building crops (especially those plowed under), and other operations whose effect extends over more than one crop; (2) the evaluation of the effect of one crop on another; and (3) the charge for land use. All these problems are interconnected. They are sometimes not only discussed together, but provision for items 1 and 2 is made by increase or contraction of the charge for land use.

1. The proper distribution of the cost of operations affecting more than one crop, especially of applied fertility, should depend on (a) the form in which fertility is applied (in forms readily soluble and deteriorating, or slowly soluble and deteriorating); (b) the type of soil (light soils assimilate and lose nutrients more quickly than heavy soils, so that residual effects are less on lighter soils); and (c) the crop grown (crops vary in their tendency to exhaust fertility). Owing to all these divergent factors, the distribution of the costs involved can be made only more or less arbitrarily. The whole problem of distributing these costs, in fact, is in a rather confused state, and ways of charging them vary considerably.⁸

It is shown by data compiled, for example, by Chilcott for the Great Plains⁹ that where two crops are grown in succession on fallowed land, the second crop also profits to some extent from the fallowing. In any case, it does not need as much land preparation as would be necessary if there had been no thoroughly prepared fallow one crop earlier. Some students therefore charge two-thirds of the cost of fallowing to the first crop and one-third to the second, but more frequently the first crop is charged with the whole cost.

The cost of manure is more frequently spread over several crops; the Cornell Agricultural Experiment Station, for example, charges 40 per cent to the first crop and 30, 20, and 10 per cent to the second, third, and fourth, respectively. But other modes of distribution are also widely used. The value of the commercial fertilizer, on the other hand, is mostly

⁸ The U.S. Bureau of Agricultural Economics leaves to the farmer all the complicated problems of distributing such costs. Its questionnaire does not ask for information on preceding and succeeding crops. As a result, all costs, such as those of fallowing, manure, and commercial fertilizer, are probably charged to the crop to which they are applied.

⁹ E. C. Chilcott, *The Relations between Crop Yields and Precipitation in the Great Plains Area. Supplement 1.—Crop Rotations and Tillage Methods* (U.S. Dept. Agr. Misc. Circ. 81, October 1931).

charged fully to the crop to which it is applied, though some kinds of commercial fertilizer display residual effects, especially on heavy soils. The great authority on accounting, E. Laur, adds the fertility left over from the preceding crop to what is applied in any form to this year's crop, and charges half of the total value to this year's crop, without regard to differences in type of fertility, type of soil, or kind of crop.

2. The effect of the hay crop on the succeeding crop or crops is probably the only such effect ever considered in cost computations; at least the writer has not encountered charges of one crop in favor of another, except as regards hay. But even this is not common, especially if the hay crop is not leguminous. Laur evidently does not ask whether the preceding crop other than a legume has a good or bad effect on the next crop. This may not be inappropriate under the very intensive methods of crop production followed in Switzerland, but it may easily lead to false conclusions for regions practicing extensive methods. In our particular study, the role of corn cannot be clearly perceived without considering its beneficial effect on the yield of small grains following it in rotation. Charges for one crop in favor of another involve, however, much arbitrariness. It is also impossible to handle these charges without introducing the factor of profitability of different crops, which ought to be avoided as far as possible in a computation at uniform rates.

The relative character of costs of crops produced in rotation is particularly apparent in the following example. Alfalfa undoubtedly increases the fertility of the soil but exhausts subsoil moisture. In regions well supplied with moisture, all small grains and many other crops yield better after alfalfa than after many other crops. Under ordinary conditions alfalfa could justly be credited with the net return for this increase. In a portion of Argentina, however, alfalfa is profitable to such an extent that it is grown on the same land as long as possible. Afterwards, corn or small grains are grown, but only so long as is necessary to condition the land for alfalfa. Ought the corn and small grains to be credited for the subsoil moisture that is accumulated while these crops are growing? Fortunately it is not necessary here to answer this question, because our interest in costs in the portion of Argentina involved is limited to comparisons between the costs of corn and wheat, both grown *after alfalfa*. If an answer had to be given, it would probably be in the affirmative. For in that portion of Argentina, subsoil moisture is the fertility factor which matters most. Alfalfa grown for a year or two is helpful and deserves credit; alfalfa grown for several years needs help and should pay for it.

Difficulties are particularly prominent in the case of such service of one crop to another as the use of a small grain as a cover crop. How much should the hay crop be charged in favor of the small grain? If the small grain were credited with the whole difference between the cost of growing hay with and without a cover, the small grain might become the most profitable crop in the rotation. Hay, on the other hand, may then seem so unprofitable that the improvement of crops grown after hay

would not be able to cover the deficit shown by the hay account. Another alternative is to give the small grain only so much credit for its service as cover crop as is needed to make the small-grain crop pay all its costs. But this procedure too is unsatisfactory, for all small grains would appear equally profitable. Actually small grains hardly ever get credit for their service as a cover crop in computations of costs. Yet the cost of producing oats in the Corn Belt would make a quite different showing (they now regularly show a great loss) if oats were credited for this service.

3. According to our assumption the charge for land use should be uniform. But there is the problem as to what is a uniform charge. The same problem arises with regard to buildings and in some other cases, but is less relevant there. A uniform charge for land use does not mean that if one crop occupies the land three months and another four months, the second should be charged more for land use. So far as each of the crops excludes the other adapted crops for a whole year, a year's rent, the usual charge in cost computations based on cash rent, seems appropriate.

But what should be the procedure if some crop interferes with the next year's crop or the next year's crop interferes with the crop of the previous year? This is not an imaginary case, or an insignificant one. Since corn is a late crop while winter grain occupies the land for a long time, the desirable crop sequence corn-winter wheat in some regions either is impossible or involves additional cost and/or unfavorable effects on yields. If one of these crops has to be dropped entirely, the proper procedure seems to be to charge half of the loss in revenue to the crop which is grown to the exclusion of the other.¹⁰ If winter wheat is grown after corn but some additional costs or losses arise, these costs or losses should probably be divided between both crops.¹¹

The use of the data.—The costs computed at uniform rates are evidently more a fiction than a reality. Where crops are grown in rotation, these costs may differ widely from actual costs. Costs at uniform rates therefore cannot be used unreservedly either by farmers in deciding on crops to be grown or by the general public including the government, even in those cases where they would be satisfied with average unit costs. If farmers should use costs computed at uniform rates for the purpose stated, the results would be large overproduction of, and loss on, principal crops, and large shortage of, and profit on, subsidiary crops. Con-

¹⁰ It actually costs less to produce corn where it can be produced in conjunction with winter wheat than where a spring grain has to be grown after corn owing to the shortness of the season. The situation is the same for winter wheat if it has to be grown in conjunction with a spring-sown small grain rather than corn.

¹¹ The problem of justly assessing the charges for land use is particularly complicated in regions where more than one crop can be grown annually on the same land. Certain combinations of crops produce two crops in one year, while some others will average only one and a half crops. In Egypt, for example, it would probably be preferable to abstain from cost computations rather than to place an equal charge for land use on all crops.

versely, if the costs computed at uniform rates were made into fixed prices by law, the inevitable result would be a large deficit of principal crops and a large surplus of subsidiary crops.

These shortcomings evidently greatly impair the value of data computed at uniform rates. But there are purposes for which costs computed at such rates are well usable. Moreover, their obviously formal and even fictitious character is a sort of guarantee that they will not be used for purposes for which they are not satisfactory. Costs at uniform rates are mostly easily recognizable or made recognizable as costs which cannot claim general validity.

It would probably be commonly agreed that costs computed at uniform rates can be safely used where similar crops are grown or may be grown in the same places in rotations either as principal or as secondary crops. Spring barley and oats are in direct competition for the same places in rotations over wide areas of the world, mostly as secondary crops. The same is true of winter wheat and winter rye, except that the competition for the place as principal crop is less rare. The requirements for factors of production and their seasonal distribution are to such an extent similar for those crops that decisions made from the difference between the costs at uniform rates and the returns for the crops are likely to be correct in most cases.

Provided the growing season is sufficiently long, replacement of a spring-sown small grain by a fall-sown small grain in a certain place in the rotation with a row crop is also frequently accomplished easily, and the comparison of costs of the two small grains as computed at uniform rates in many cases provides a fair idea of the financial prospects of such rearrangement. But replacement of a spring-sown small grain by a fall-sown grain in a rotation with a row crop gives rise to some extra costs if the season is short, and some way has to be found for distributing these costs among the crops involved. Further complications arise if a row crop—for example, corn—has to be substituted for a small grain, or vice versa, owing to the materially diverging seasonal distribution of labor and power requirements. Still, so long as the place in the rotation remains the same, costs computed at uniform rates remain usable with some adjustments, sometimes minor.

The possibility of using costs computed at uniform rates for comparisons of the positions of different crops in the same places of rotations is of great importance. Let us assume, for example, that the per-cental cost of producing spring wheat in North Dakota at uniform rates is 40 per cent larger than that of spring barley. If wheat exceeds barley in price by 65 per cent, the advantage of growing wheat rather than barley—either of them as a principal or subsidiary crop—is equivalent to approximately 20 per cent of the cost or price of wheat, or about \$2.00 per acre. The knowledge of this margin makes it possible to estimate the price at which wheat will begin to cede acreage to barley. If the computation is not limited to average conditions but cost ratios are available also for land

less adapted to wheat and if, moreover, the amount of such land is known, rather accurate conclusions can be drawn as to the competitive position of wheat and barley in that area. Such information is valuable as a check even in those cases where information can be obtained from the analysis of the response of acreages to prices by statistical methods.¹²

The costs computed at uniform rates are less useful in analysis of crops grown in different places of rotations, but they are not entirely useless. If the costs of two crops produced in different places in rotations, compared with prices, show different profitableness, the significant conclusion can mostly be drawn that one crop has to be subordinated to the other.

The discussion of average and marginal costs (pp. 563-65) shows clearly that the unit cost of a crop (excluding the charge for land use) and the contribution toward the cost of land use must be expected to change with the change in the proportion of acreage devoted to it. Hence costs computed at uniform rates are least useful for decisions whether it would pay to increase the proportion of the acreage devoted in the rotation to a certain crop at the expense of another. Still, in the above example of wheat and barley in North Dakota, for example, it is not very difficult for the farmer to figure out whether the apparent deficit of \$2.00 per acre which is involved in growing barley rather than spring wheat at uniform rates for labor, power, and the like, can be made up by savings resulting from a fuller use of all the factors of production, and by improvement in yields made possible by growing, instead of wheat exclusively, some barley along with much wheat. In other cases, only a rather vague idea of the situation can be had. In many decisions as to the proportions of crops to grow, the farmer should better resort to special computations based on data on physical requirements of the crops and their seasonal distribution. The need for such data is recognized by all students, whether or not they favor computations of money costs.

The general public can of course not make much use of costs computed at uniform rates. It cannot be expected to be able to distinguish between crops competing for the same places in rotations and crops of supplementary type, and to make the adjustments which may be needed. Costs computed at uniform rates can be made usable for the general public only by some fundamental rearrangement. A simple method for such a rearrangement is discussed in the last section of this note.

OTHER COST COMPUTATIONS

Although compilers of costs of individual crops aim at actual costs, most cost computations, owing to deficiencies of the procedure employed, yield results differing only slightly from those computed at uniform rates;

¹² The latter is frequently impossible, and even more often yields results of rather doubtful value, because data for long periods of time are needed and the assumption, seldom correct, has to be made that the relationship remained fairly constant during that long period.

and since costs at uniform rates sometimes differ widely from actual costs, so also do the costs as actually computed.

The common procedures in computing costs of individual crops can undoubtedly be improved. But it is questionable whether it is possible to make the computed costs coincide with the actual costs. As yet nobody has suggested a practical method. The great difficulties are implied in the fact that agencies compiling cost data have continued to use the same procedures almost for decades, in the face of the severest criticism.

Computation of the data.—The usual procedure in cost-of-production computations is to charge to each crop at actual cost the seed and other materials, and the items hired specifically for it, and to distribute at uniform rates the costs of all other factors of production among the crops using them. Thus the owner's labor and labor hired per season is charged at so much per hour or day,¹³ while labor hired for specific operations is charged to the specific crops to which the operations pertain. If a farm owns a thresher or other machine, the cost of its use will be charged at a uniform rate to all crops threshed with it, while, if threshing is hired, the actual cost is charged to each crop. This charge may be higher at the peak of the harvest and less before and after. The described procedure is followed by the U.S. Bureau of Agricultural Economics in computation of the data used above in Part III, and by many other agencies.

If the factors of production owned by the farm prove insufficient at the peak, it usually occurs in operations needed for the dominant crop, mostly when this is harvested. Provided this crop is dominant throughout a whole region, as for example wheat, corn, or cotton in their respective belts, to charge the actual cost of production factors hired for specific operations is equivalent to charging the dominant crop rates higher than uniform ones. This difference in the method of charging would make the costs computed by the usual accounting methods substantially different from those computed at uniform rates, if not for the fact that most farmers own their sources of power, machinery, and almost all the labor, and that a large portion of the hired labor is hired by the year or season.

The attention of students dissatisfied with existing cost data is therefore largely directed toward finding a more exact way of distributing the cost of factors of production owned by the farm or hired for more than one operation. Some students see a suitable way to this end in charging owned factors at market rates prevailing at the time when the operation is performed.¹⁴ Unfortunately, however, market rates are frequently very

¹³ Hours are preferable, since the days are shorter in the winter and longer in the summer.

¹⁴ J. D. Black and C. M. Purves found that corn in Minnesota appears less profitable, and oats more profitable, if monthly wage rates instead of annual (or seasonal) rates are used in the computation of the charge for the labor of the farmer and the help hired on a yearly or seasonal basis. The difference was slight, however. Thanks

difficult or impossible to ascertain. Moreover, the seasonal variations in the value of labor, the principal item, and of some other factors also, are smaller on the market than on the farm. The labor of the farmer is in general worth more than hired labor, while at slack time it may be valued by him at almost nothing. It would not be easy to make an allowance for the better quality of the farmer's own work, but it would be even more difficult to establish the values placed by different farmers on their leisure. Similarly, a farmer will usually leave his horses and machinery idle, if they are not needed on his own farm, even though a market price for their use may exist at the time.

It has been repeatedly recommended to charge to the crop in question the opportunity cost of factors of production, i.e., what could be realized by use of the factor in an alternative enterprise. This procedure has probably never been followed in practice, owing to the technical difficulties involved. Moreover, the opportunity cost applied to accounting would frequently result in undercharges. In theory, which operates with infinitesimal quantities, the difference between what the factor of production can return in this or an alternative enterprise can be taken to be equal to zero. But accounting operates with sizable quantities; the charge for land use may be the one most affected by the procedure. The cost of wheat would obviously be underestimated if wheat grown on good wheat land, but with pasture as the only alternative, were charged for the use of land what this could bring as pasture. The price of such land and its rental value are actually based on what it can bring in wheat. The same is true of all other cases where the profitableness of one crop far exceeds that of any alternative, as for example cotton in the Cotton Belt.

The charge for land use most usually employed in cost accounting is an equal charge on all crops grown on the land, without regard to the length of time occupied by the crop (unless the time is more than a year). The Canadian Bureau of Statistics took particular pains to insure this type of charge.¹⁵ Laur also charges a certain percentage of the value of the land to all crops grown on it, the only refinement being that each piece of land is evaluated separately. The U.S. Bureau of Agricultural

are due to Mr. Purves for access to an unpublished manuscript. See also J. D. Black, "Unit Cost of Production of Farm Products," *Introduction to Production Economics*, pp. 269-70.

¹⁵ The instructions read in part: "*Rental value of land.*—Where land is rented the average rent paid per acre in the locality should be given in the schedule; but where land is owned, the rental value will be best ascertained by calculation from the value of the land, the prevailing rate of interest for money borrowed on security of real estate and the local taxes paid per acre calculated for improved land. You are requested therefore kindly to give for your locality in the spaces provided (a) the value of land per acre, (b) the usual rate of interest for money on land mortgage, and (c) the total taxes paid per acre calculated for improved land." Canada, Dominion Bureau of Statistics, *Cost of Grain Production in Canada, 1923* (partly reprinted from the *Monthly Bulletin of Agricultural Statistics*, June 1924), 1924, p. 2.

Economics likewise seems to prefer a uniform charge. But it definitely excludes share rent only as a basis for computing the charge for land use (which rather regularly leads to unequal rates), and insists on the use of cash rent as the basis. The question in its questionnaire is, "For what would your land cash rent?" Since it is not specified that the cash rent should be equal for all crops, different cash rents can be given by the reporting farmers for different crops.¹⁶

The exclusion of share rent as a basis for determining the charge for land use is a departure from the practice that factors of production hired for some specific crop or crops are charged directly to it or them. The payment due for each crop grown on land rented on this basis is definitely known and can conveniently be charged to it. The practice followed in Argentine statistics of computing the charge from the price of the land and the interest rate for the owners, from the cash rent for the cash tenant, and from the share rent for the share tenant, seems to be more logical. The computed separate charges are then weighted by the amount of land operated under the different systems. The Nebraska Agricultural Experiment Station goes one step further by computing the cost of production only for that portion of the crop which goes to the share tenant.

The use of share rent rather than of cash rent for computing the charge for land use would be a great improvement, if the renting of land on shares were not subject to the same routine as renting for cash. The practice prefers an average rent for the whole farm to an appraisal of the value of each portion of it for each specific crop: in the case of cash rent this average rent is an *equal sum of money per acre*, and in case of share rent an *equal percentage of all crops*. Exceptions from the use of equal percentages, it is true, are sometimes made in share-renting. In the Corn Belt, for example, grass land is usually rented on cash basis to tenants who rent the grain land on share basis, and in exceptional cases a lower percentage of the oats crop than of the corn crop is agreed upon as the share rent.¹⁷ Still, in such important regions as the wheat and corn belts, the principal crops, which actually bear a more than pro-rata share of the land rent, yield a larger gross return per acre than the usual secondary crops of those regions. Even an equal percentage of the larger gross return means a higher charge for land use on them.

The use of the data.—So far as there is a difference between the commonly computed costs and costs computed at uniform rates, the former are nearer to actual costs. But since the difference, if any, is small, small also is the superiority of the data as commonly computed, and these are almost as inadequate for general use as costs computed at uniform rates. This can be easily demonstrated by the data of the U.S. Bureau

¹⁶ Shifting to farmers the responsibility for the selection of the charge for land use and for most other decisions, and the resulting indefiniteness, of course do not improve the value of the resulting data.

¹⁷ Information from Dr. Rainer Schickele of Iowa State College.

of Agricultural Economics. According to one of its recent publications,¹⁸ the per-cental cost of oats, at yields of 1927-36 and prices of factors of production in 1937, was 27 per cent higher than the cost of corn in Iowa and Illinois, and 18 per cent higher in the group of states comprising Ohio, Indiana, Michigan, Wisconsin, and Minnesota, as well as in the group of states consisting of Missouri, Nebraska, Kansas, South and North Dakota. With corn prices actually somewhat higher than oats prices, it is easy to imagine the huge amounts of oats which would be produced if fixed prices were introduced and fixed prices of oats were set 20 to 25 per cent above those of corn. In the hard-spring-wheat region, furthermore, the fixed price of oats would be smaller than that of wheat by not quite 20 per cent, while sufficient oats are produced at market prices 35-40 per cent less than that of wheat.

Fortunately, cost data have never been used in this country for establishing ratios between fixed or similar prices of different grains. But the alternative chosen by the lawmakers also was of doubtful value. The same base for computing parity prices (average prices in 1909-14) has been established by law for oats and other grains in the face of the tremendous decline in horse numbers since the base period, with accompanying decline in oats prices relative to prices of other feed grains and feeds generally. This disregard of economic facts might not have occurred if cost-of-production data were not in such a confused state.

Students not specializing in cost-of-production studies also are easily led astray. After having pointed out that, according to the cost-of-production data of the Bureau of Agricultural Economics, Illinois farmers make a profit on corn while South Carolina farmers lose on it, Huntington and others¹⁹ conclude: "The way in which farmers devote much land to corn even when the yield is poor is astonishing." The farmers are not in error. Corn is the principal crop in Illinois, and its cost as computed by the Bureau is relatively less than the actual cost. In South Carolina corn is a secondary crop, and the computed cost is relatively higher than the actual cost.

It is very difficult to find a use for which the costs as commonly computed are good. These are not actual costs, i.e., average costs of the whole produce; they may be almost as remote from these as costs at uniform rates. But the costs as commonly computed also cannot be used conveniently for comparing the competitive position of different crops for the same places in rotations, because for this purpose costs at uniform rates are usually needed. The difficulty encountered in using the available data for this purpose is the larger because it is usually impossible to ascertain to what extent rates charged on one crop differ from rates charged on another.

The use of costs at uniform rates and at rates as commonly charged

¹⁸ *Crops and Markets*, December 1938, XV, 298-99.

¹⁹ Ellsworth Huntington and others, *Economic and Social Geography* (New York, 1933), p. 210.

in comparisons of the competitive power of different crops reminds one of the comparisons of the quality of horses from results of races. To make a reliable comparison one needs data on races in which all horses carry the same weights. When horses run in handicaps under unequal weights the comparison is uncertain owing to the difficulty of making allowance for the extra weight carried by some of the horses. But in using the costs commonly computed for comparisons, we mostly do not even know what extra weights in the form of higher rates had been imposed on one of the crops. Thus the available cost data frequently are good neither for the broad uses for which actual costs could be employed nor for the limited uses for which costs at uniform rates are useful. The writer has found no other way than to use in the text primarily data computed at uniform rates.

ADJUSTED COSTS

Thus costs computed in the common way and, in fact, in any *practical* way, are not suitable for general use. The use of them by the general public is particularly dangerous. In those infrequent cases where data on the cost of production of individual crops are reproduced in year-books and similar publications intended for a wider public than a few experts, it is probably always with the hope that they will not be used. All such data, if published, should be accompanied by a statement of their limitations, though such statements might help little because foot-notes and similar qualifications of figures are generally disregarded by readers.

If the costs of production of individual crops computed by the accounting method are to be made usable not only as indices showing relations in specific cases, but also as absolute figures showing the actual cost of each crop, the data must be correspondingly adjusted.

Under perfect competition, costs (including the charge for land use) and prices must coincide in the long run. Even more can it be expected that the *relation* between the costs of two crops would coincide with the relation between their prices. We of course do not know to what extent competition in agriculture is imperfect, but we do know that cost computations are far from perfect. Hence it may be the smaller evil to *distribute the total cost of production of all crops* grown in the same rotations among the individual crops *in proportion to their market prices*. The *relation* between the costs thus adjusted may be expected to agree with the factual situation better than it can be made to agree by any direct itemized computation of costs.

The adjusted costs will not be simply market prices arrived at in a complicated roundabout way. While the *relation* between the adjusted costs will be the same as that between market prices, the *level* of such costs will be either higher or lower than the level of market prices, depending on the evaluation of the factors of production. The connection between a given evaluation of factors of production and the costs of pro-

duction of individual crops—the principal aim of cost computations—would be established in as perfect form as seems possible under the circumstances.

The suggested procedure is widely used by Laur, but he employs it only in those cases where either the accounting is not sufficiently detailed to permit a computation of separate costs, or where the nature of outlays is such that he does not find another basis for distributing them among the different goods. In other words, costs computed directly and arrived at by distributing joint outlays by methods other than in proportion to market prices are the preferred ones, while distributing the outlays in proportion to market prices is a last resort. For Laur the procedure here proposed is merely a practical device, and he does not stress its agreement with the requirements of economic theory.

While Laur uses the adjustment of computed costs in proportion to market prices simply as one of many practical devices in accounting, the same principle seems to have received wide application for very broad purposes in proposals for computing "just" or "necessary" prices of farm products by farmers' organizations during the last fifteen years. Section 2*b* of the so-called "Cost of Production Bill" ("Agricultural Equality Act of 1939") sought to prescribe that the average individual farm be considered a business unit. This and other statements of the bill were so interpreted that the total costs computed for each unit should be distributed among all products produced in proportion to their market prices. The procedure undoubtedly has merits for the purposes set, although, for the huge increases of current prices aimed at by the bill, equal percentage increases of all farm prices might prove somewhat mechanical. But the device seems to be well adapted for the more modest purpose of adjusting costs computed for crops grown in the same rotation without assurance that allotment of costs to individual crops has been done properly.

APPENDIX TABLES

TABLE I.--WORLD ACREAGE OF FIVE GRAINS, AVERAGE 1932-36*

Country	Million acres					Percentage of world total				
	Wheat	Rye	Barley	Oats	Corn	Wheat	Rye	Barley	Oats	Corn
North America ^a	77.1	3.6	14.3	49.7	109.5	22.73	3.36	16.05	35.61	53.01
Canada ^a	25.4	0.7	3.9	13.6	0.2	7.48	0.63	4.35	9.71	0.07
United States ^a	50.2	2.9	10.0	36.2	99.5	14.79	2.73	11.28	25.90	48.19
Mexico	1.2	...	0.4	0.0	7.5	0.35	...	0.42	0.01	3.64
South America	19.9	0.9	1.8	2.3	23.4	5.86	0.88	2.06	1.64	11.34
Brazil	0.4	0.0	0.0	0.0	10.1	0.12	0.03	0.03	0.02	4.89
Chile	1.9	0.0 ^b	0.2	0.2	0.1	0.56	0.02 ^b	0.20	0.16	0.06
Uruguay	1.1	0.0	0.0	0.2	0.6 ^c	0.32	0.00	0.03	0.13	0.27 ^c
Argentina	16.1	0.9	1.4	1.9	11.6	4.75	0.83	1.53	1.32	5.64
Europe	166.1	102.4 ^d	47.0 ^d	83.9 ^d	40.0	48.98	94.95 ^d	52.89 ^d	60.06 ^d	19.38
Great Britain	1.7	0.0 ^e	0.9	2.6	...	0.51	0.01 ^e	1.03	1.85	...
Eire	0.1	0.0	0.1	0.6	...	0.03	0.00	0.14	0.43	...
Belgium ^f	0.4	0.5	0.1	0.7	...	0.11	0.47	0.10	0.49	...
Netherlands	0.4	0.5	0.1	0.3	...	0.10	0.44	0.09	0.24	...
France	13.3	1.7	1.8	8.2	0.8	3.92	1.56	2.01	5.89	0.41
Portugal	1.4	0.4	0.2	0.5	1.0	0.40	0.34	0.20	0.35	0.50
Spain	11.2	1.5	4.7	1.8	1.1 ^e	3.29	1.35	5.24	1.28	0.52 ^e
Italy	12.4	0.3	0.5	1.1	3.6	3.66	0.26	0.56	0.77	1.75
Greece	1.9	0.2	0.5	0.3	0.6	0.55	0.16	0.59	0.24	0.30
Switzerland	0.2	0.0	0.0	0.0	0.0	0.05	0.04	0.01	0.02	0.00
Germany	5.4	11.1	4.0	7.5	0.0 ^g	1.60	10.32	4.46	5.37	...
Czechoslovakia	2.3	2.5	1.6	1.9	0.4	0.67	2.33	1.84	1.39	0.17
Austria	0.6	0.9	0.4	0.7	0.2	0.17	0.88	0.46	0.53	0.08
Denmark	0.3	0.3	0.9	0.9	...	0.08	0.32	0.97	0.68	...
Norway	0.0	0.0	0.1	0.2	...	0.01	0.01	0.16	0.16	...
Sweden	0.7	0.6	0.3	1.6	...	0.21	0.51	0.29	1.18	...

Country	Million acres					Percentage of world total				
	Wheat	Rye	Barley	Oats	Corn	Wheat	Rye	Barley	Oats	Corn
Poland	4.3	14.2	2.9	5.5	0.2	1.26	13.14	3.31	3.93	0.11
Lithuania	0.5	1.2	0.5	0.9	...	0.15	1.13	0.57	0.62	...
Latvia	0.3	0.6	0.5	0.8	...	0.09	0.59	0.52	0.57	...
Estonia	0.2	0.4	0.3	0.3	...	0.05	0.33	0.29	0.25	...
Finland	0.1	0.6	0.3	1.1	...	0.04	0.54	0.36	0.82	...
Hungary	3.9	1.6 ^a	1.2	0.5	2.8 ⁱ	1.16	1.48 ^a	1.30	0.39	1.37 ⁱ
Yugoslavia	5.1	0.6	1.0	0.9	6.4	1.52	0.58	1.17	0.64	3.08
Rumania	7.9	0.9	4.3	2.0	12.4	2.32	0.88	4.79	1.43	5.99
Bulgaria ^f	3.0	0.5	0.6	0.3	1.8	0.89	0.46	0.63	0.21	0.85
USSR ^j	88.4	61.2 ^o	19.4 ^c	42.3 ^c	8.6	26.08	56.77 ^o	21.77 ^o	30.27 ^o	4.14
Asia	49.6	0.7	16.3	1.1	18.2	14.64	0.69	18.34	0.81	8.79
Turkey ^f	8.0	0.7	3.9	0.5	1.0	2.37	0.69	4.39	0.35	0.49
Palestine	0.4 ^o	...	0.5	...	0.0 ^k	0.13 ^r	...	0.61	...	0.01 ^p
British India	34.2	...	6.4	...	5.9 ^c ^l	10.09	...	7.18	...	2.87 ^c ^l
Indo-China .....	...	...	...	...	0.7 ^m	...	...	...	...	0.36 ^m
Netherlands Indies .....	...	...	...	...	5.2 ^c ⁿ	...	...	...	...	2.50 ^c ⁿ
China ^o	49.9	...	16.5	2.5 ^o	11.2	...	...	...	...	...
Manchukuo	2.9	...	0.4 ^r ^p	...	2.8	0.84	...	...	...	1.37
Japan	1.5	...	1.9	0.3	0.1	0.45	...	2.18	0.22	0.06
Africa	12.7	0.1	9.0	1.1	15.0	3.73	0.12	10.17	0.80	7.25
French Morocco	3.2 ^o	0.0	3.9 ^o	0.1	1.0	0.93 ^r	0.00	4.34 ^o	0.05	0.47
Algeria	4.0	0.0	3.2	0.5	0.0	1.19	0.00	3.63	0.33	0.01
Tunis	1.9	...	1.1	0.1	0.0 ^r	0.55	...	1.29	0.04	0.02 ^r
Egypt	1.5	...	0.3	...	1.7	0.45	...	0.34	...	0.83
Union of South Africa ..	1.8	0.1 ^a	0.1 ^o	0.5 ^o	5.8 ⁱ	0.53	0.11 ^a	0.08 ^o	0.37 ^o	2.80 ⁱ
Australia	13.5	0.0	0.5	1.4	0.3	3.98	0.01	0.54	1.02	0.14
World	339.0	107.8 ^d	88.9 ^d	139.7 ^d	206.6	100.00	100.00	100.00	100.00	100.00

* See notes under Table III.

TABLE II.—WORLD PRODUCTION OF FIVE GRAINS, AVERAGE 1932-36*

Country	Million centals					Percentage of world total				
	Wheat	Rye	Barley	Oats	Corn	Wheat	Rye	Barley	Oats	Corn
North America ^a	559.9	21.6	132.7	403.2	1,248.7	20.06	2.10	15.20	29.56	53.08
Canada ^a	180.2	3.5	34.9	114.7	3.4	6.46	0.34	4.00	8.41	0.15
United States ^a	370.6	18.1	96.2	288.4	1,187.5	13.28	1.76	11.02	21.15	50.48
Mexico	6.8	...	1.6	0.1	39.1	0.25	...	0.18	0.00	1.66
South America	170.0	5.9	19.7	21.1	342.2	6.09	0.57	2.26	1.55	14.55
Brazil	3.3	0.4	0.2	0.3	128.8	0.12	0.03	0.03	0.02	5.47
Chile	18.6	0.2 ^a	2.5	2.1	1.5	0.67	0.02 ^a	0.29	0.15	0.06
Uruguay	6.6	0.0	0.1	0.8	2.9 ^c	0.24	0.00	0.02	0.06	0.12 ^c
Argentina	139.0	5.4	14.6	17.9	194.0	4.98	0.52	1.67	1.31	8.25
Europe ^d	1,542.7	994.3	505.4	915.9	475.4	55.28	96.69	57.90	67.15	20.21
Great Britain	35.6	0.2 ^c	17.1	47.3	...	1.27	0.02 ^c	1.96	3.47	...
Eire	2.5	0.0	2.9	13.2	...	0.09	0.00	0.33	0.97	...
Belgium ^f	9.3	11.3	2.1	16.4	...	0.33	1.10	0.24	1.20	...
Netherlands	9.4	9.7	1.9	6.5	...	0.34	0.94	0.22	0.47	...
France	188.9	17.9	23.3	103.8	10.8	6.77	1.74	2.68	7.61	0.46
Portugal	11.3	2.4	0.9	1.9	7.0	0.41	0.23	0.10	0.14	0.30
Spain	94.7	11.8	51.6	14.5	15.9 ^c	3.39	1.15	5.91	1.07	0.67 ^c
Italy	157.9	3.4	4.7	11.7	63.3	5.66	0.33	0.54	0.86	2.69
Greece	14.1	1.3	4.3	2.3	5.2	0.51	0.12	0.49	0.17	0.22
Switzerland	3.1	0.7	0.2	0.5	0.1	0.11	0.07	0.02	0.04	0.00
Germany	106.9	174.4	73.5	132.5	...	3.83	16.96	8.42	9.72	...
Czechoslovakia	35.3	39.1	26.3	29.4	5.3	1.27	3.80	3.02	2.15	0.23
Austria	8.4	13.1	6.4	9.6	3.2	0.30	1.27	0.73	0.70	0.14
Denmark	7.4	5.4	21.7	21.7	...	0.26	0.53	2.49	1.59	...
Norway	0.8	0.3	2.5	4.0	...	0.03	0.02	0.29	0.29	...
Sweden	14.8	9.7	4.7	26.5	...	0.53	0.94	0.54	1.95	...

Country	Million centals					Percentage of world total				
	Wheat	Rye	Barley	Oats	Corn	Wheat	Rye	Barley	Oats	Corn
Poland	43.0	143.9	31.6	56.7	2.1	1.54	13.99	3.62	4.16	0.09
Lithuania	5.6	13.1	5.3	8.0	...	0.20	1.28	0.61	0.58	...
Latvia	3.8	7.6	4.3	7.6	...	0.14	0.74	0.49	0.55	...
Estonia	1.5	4.2	2.1	2.9	...	0.05	0.41	0.24	0.21	...
Finland	2.0	7.7	4.0	14.9	...	0.07	0.75	0.46	1.09	...
Hungary	47.7	16.7	14.6	6.4	45.6 ^d	1.71	1.62	1.63	0.47	1.94 ^d
Yugoslavia	47.9	4.6	9.1	7.0	95.8	1.72	0.45	1.04	0.51	4.07
Rumania	57.2	7.5	30.0	15.2	116.3	2.05	0.73	3.41	1.12	4.95
Bulgaria ^f	30.2	4.6	6.3	2.4	20.0	1.08	0.45	0.73	0.17	0.84
USSR ^e	602.0	483.4	153.6	351.8	81.9	21.57	47.00	17.60	25.79	3.48
Asia	334.6	6.0	156.1	9.2	167.1	11.99	0.59	17.89	0.68	7.10
Turkey ^g	60.1	6.0	35.1	4.1	11.1	2.15	0.59	4.02	0.30	0.47
Palestine	1.6	...	1.1	...	0.1 ^h	0.06	...	0.13	...	0.00 ^h
British India	210.6	...	53.7	...	46.1 ^c	7.55	...	6.15	...	1.96 ^c
Indo-China .....	...	...	...	...	9.2	...	...	...	...	0.39
Netherlands Indies .....	...	...	...	...	35.5 ^c	...	...	...	...	1.51 ^c
China ^o	494.3	...	174.5	19.4 ^o	137.8	...	...	...	...	...
Manchukuo	19.7	...	4.1 ^v	...	39.5	0.71	...	...	...	1.68
Japan	25.8	...	35.4	3.5	1.5	0.92	...	4.06	0.26	0.06
Africa	80.5	0.5	54.4	6.3	114.9	2.88	0.05	6.23	0.46	4.88
French Morocco	15.4 ^q	0.0	26.2 ^q	0.5	4.2	0.55 ^q	0.60	3.01 ^q	0.03	0.18
Algeria	20.2	0.0	16.7	3.2	0.1	0.72	0.00	1.92	0.23	0.00
Tunis	7.8	...	4.6	0.4	0.1 ^r	0.28	...	0.52	0.03	0.01 ^r
Egypt	26.2	...	5.0	...	36.4	0.94	...	0.57	...	1.55
Union of South Africa ..	9.3	0.5 ^o	0.7 ^o	2.2 ^o	30.9 ^t	0.33	0.05 ^o	0.07 ^o	0.16 ^o	1.31 ^t
Australia	98.3	0.1	4.2	6.9	4.0	3.52	0.01	0.48	0.51	0.17
World ^s	2,790.9	1,028.3	872.8	1,364.0	2,352.4	100.00	100.00	100.00	100.00	100.00

* See notes under Table III.

TABLE III.—WORLD YIELD PER ACRE IN FIVE GRAINS, AVERAGE 1932-36*

(Centals per acre)

Country	Wheat	Rye	Barley	Oats	Corn	Country	Wheat	Rye	Barley	Oats	Corn
North America ^a	7.2	5.7	9.1	8.0	11.3	Denmark	26.4	15.5	25.2	23.0	...
Canada ^a	7.0	5.1	9.0	8.5	22.6	Norway	16.8	16.5	17.3	17.7	...
United States ^a	7.4	5.9	9.3	7.9	11.8	Sweden	21.1	17.5	18.0	16.1	...
Mexico	5.8	...	4.2	7.7	5.2	Poland	10.0	10.2	10.7	10.3	9.1
South America	8.5	6.1	10.7	9.2	14.5	Lithuania	10.9	10.7	10.4	9.3	...
Brazil	8.4	9.5	10.7	10.9	12.8	Latvia	12.0	11.9	9.4	9.5	...
Chile	9.9	6.4 ^b	14.5	9.5	12.2	Estonia	9.7	11.7	8.1	8.4	...
Uruguay	5.9	2.9	6.0	3.9	5.2 ^c	Finland	15.3	13.4	12.8	13.1	...
Argentina	8.6	5.9	10.7	9.6	16.2 ^e	Hungary	12.1	10.4 ^a	12.7	11.6	16.1 ^t
Europe ^d	9.3	9.7	10.7	10.9	11.9	Yugoslavia	9.3	7.5	8.7	7.9	15.0
Great Britain	20.5	14.6 ^e	18.7	18.3	...	Rumania	7.2	7.9	7.0	7.6	9.4
Ire	22.8	16.8	23.0	21.8	...	Bulgaria ^f	10.1	9.3	11.4	7.9	11.3
Belgium ^f	24.0	21.9	23.6	23.9	...	USSR ^g	7.0	7.9	7.9	8.2	9.0
Netherlands	26.8	20.6	25.4	19.5	...	Asia	6.8	8.1	9.5	8.1	9.2
France	14.2	10.6	13.0	12.6	12.8	Turkey ^h	7.5	8.1	8.9	8.7	10.9
Portugal	8.2	6.6	5.4	4.1	6.8	Palestine	3.5 ^c	...	2.0	...	4.6 ^b
Spain	8.5	8.1	11.1	8.1	14.6 ^c	British India	6.2	...	8.4	...	7.8 ^c
Italy	12.8	12.2	9.5	10.9	17.5	Indo-China .....	...	...	...	...	12.1 ^r
Greece	7.7	7.1	8.1	7.0	8.4	Netherlands Indies .....	...	...	...	...	8.6 ^o
Switzerland	19.2	18.3	16.4	18.1	25.3	China ^g	9.9	...	10.8	7.7 ^o	12.3
Germany	19.6	15.7	18.6	17.7	...	Manchukuo	7.0	...	9.2 ^p	...	13.9
Czechoslovakia	15.6	15.4	16.1	15.1	16.1 ^w	Japan	16.8	...	18.3	11.4	12.3
Austria	14.5	13.8	15.5	12.9	20.0						

Country	Wheat	Rye	Barley	Oats	Corn	Country	Wheat	Rye	Barley	Oats	Corn
Africa	6.4	4.0	6.1	5.6	7.7	Egypt	17.3	...	16.4	...	21.4
French Morocco.....	5.0 ^a	4.0	6.9 ^a	6.9	4.2	Union of South Africa..	5.2	4.1 ^a	8.8 ^a	4.4 ^a	5.2 ^a
Algeria	5.0	5.2	5.2	7.0	6.1	Australia	7.2	7.8	8.7	5.0	13.7
Tunis	4.2	...	3.7	6.2	2.7 ^r	World ^a	8.2	9.5	9.8	9.7	11.3

* Data from *International Yearbook of Agricultural Statistics, 1937-38* (International Institute of Agriculture, Rome, 1938). The approximate world totals, and subtotals by continents, are those given in the *Yearbook*; they do not include figures for China and Iraq, as well as several other countries with small acreage and production. Data by countries include only selected countries. Dots indicate that no data were given in the source; the crop so designated usually either is not grown or is grown only in negligible quantities in the country specified.

^a Data for the United States and Canada, and the subtotal for North America, were greatly affected by exceptional droughts in the period specified.

^b Average of 1932 and 1936.

^c Average of 1932-35.

^d The figures were arrived at by adding averages for all countries considered by the International Institute except USSR, and adding the 1932-35 average for USSR.

^e Figures for England and Wales only.

^f The methods of collecting statistics having been modified in 1934 in Belgium and in 1936 in Bulgaria, the figures for these years onwards are not exactly comparable with those of preceding years.

^g Not included in totals.

^h Rye and meslin.

ⁱ Main crop, excludes corn in gardens.

^j Territory in Europe and Asia.

^k Average of 1932, 1933, and 1935.

^l Excludes Burma.

^m 1935 and 1936 figures estimated.

ⁿ Java and Madura.

^o Average of 1933-36.

^p 1936 only.

^q Figures collected for revenue purposes.

^r Corn and sorghum.

^s Average of 1933-35.

^t Europeans' crop.

^u Average of 1935 and 1936.

^v Excludes 1935.

^w Last three years are for unmixed crop only.

^x Average of 1932-34.

TABLE IV.—ACREAGES IN SMALL GRAINS SOWN IN FALL AND SPRING IN SPECIFIED COUNTRIES, 1935*

Country	Thousand acres			Per-centage spring sown	Thousand acres			Per-centage spring sown
	Fall	Spring	Total		Fall	Spring	Total	
	RYE				WHEAT			
USSR	57,132	875	58,007	1.5	30,762	60,784	91,566	66.4
United States .....	...	...	6,494	(0+)	47,064	22,143	69,207	32.0
Canada	652	146	798	18.3	685	23,560	24,245	97.2
Belgium .....	...	...	529	(0+)	381	6	387	1.6
Netherlands .....	...	...	519	(0+)	320	60	380	15.8
France .....	...	...	1,668	(0+)	18,108	143	13,251	1.1
Spain	1,415	...	1,415	0.0	11,253	...	11,253	0.0
Germany	11,068	167	11,255	1.5	4,754	470	5,224	9.0
Czechoslovakia	2,464	50	2,514	2.0	2,250	137	2,387	5.7
Austria	903	40	944	4.3	569	32	601	5.4
Norway	11	4	15	27.5	4	54	59	92.8
Sweden	540	21	561	3.7	531	143	674	21.2
Poland	14,228	64	14,292	0.4	3,756	579	4,335	13.4
Lithuania	1,258	9	1,267	0.7	414	122	536	22.8
Latvia	658	10	668	1.6	210	137	347	39.4
Estonia .....	...	...	357	(0+)	52	103	155	66.5
Finland .....	...	...	598	(0+)	60	114	174	65.4
Hungary	1,525	71	1,596	4.5	4,154	64	4,218	1.5
Yugoslavia	541	102	643	15.9	5,367	94	5,461	1.7
Rumania	940	21	960	2.2	7,740	756	8,496	8.9
Bulgaria (1936)	457	33	489	6.7	2,941	14	2,955	0.5

* Acreage data direct from official sources for the United States and Canada; for other countries from *International Yearbook of Agricultural Statistics, 1937-38* (for Italy and Latvia from preceding issue). Data are for sown acreage for the USSR, the United States, Canada, Germany, Czechoslovakia, Hungary, and Yugoslavia; otherwise for harvested acreage differing little from sown acreage. For France, Germany, and Czechoslovakia, wheat acreages include small acreages in spelt. For Hungary, fall-sown rye acreage includes meslin. For Bulgaria the data are for 1936, since comparable data for 1935 are not available. (Footnote continued on next page.)

TABLE IV.—Continued

Country	Thousand acres			Per-centage spring sown	Thousand acres			Per-centage spring sown
	Fall	Spring	Total		Fall	Spring	Total	
	BARLEY				OATS			
USSR	1,151	20,452	21,604	94.7	...	...	45,269	(100—)
United States .....	...	...	13,140	(85-90)	...	...	40,690	(92-94)
Canada .....	...	...	3,887	(100)	...	...	14,096	(100)
Belgium	79	17	96	17.7	...	...	714	(100—)
Netherlands	37	64	100	63.3	...	...	316	(100—)
France	438	1,349	1,787	75.5	2,169	5,932	8,101	73.2
Spain	4,549	...	4,549	0.0	1,848	...	1,848	0.0
Germany	953	3,011	3,970	75.9	...	...	6,915	(100)
Czechoslovakia	14	1,586	1,600	99.1	...	...	1,921	(100)
Austria	21	382	403	94.9	...	...	735	(100)
Norway .....	...	...	153	(100)	...	...	215	(100)
Sweden .....	...	...	260	(100)	...	...	1,658	(100)
Poland	80	2,931	3,011	97.3	...	...	5,521	(100)
Lithuania .....	...	...	508	(100)	...	...	841	(100)
Latvia .....	...	...	477	(100)	...	...	822	(100)
Estonia .....	...	...	258	(100)	...	...	342	(100)
Finland .....	...	...	315	(100)	...	...	1,164	(100)
Hungary	248	832	1,080	77.1	...	...	507	(100—)
Yugoslavia	597	473	1,071	44.2	...	...	942	(100—)
Rumania	190	3,889	4,079	95.3	...	...	1,970	(100—)
Bulgaria (1936)	425	111	537	20.7	...	...	299	(100—)

The percentages are mostly computed from the acreage data given. Where subdivision between fall-sown and spring-sown acreage is not given, the percentages (put in parentheses) are our own approximations. These are given as (100) when we are satisfied that a certain grain cannot be grown as a winter crop with a reasonable chance of success; as (100—) where the climate does not entirely exclude the growing of winter grain but there is evidence that practically none is grown; and as (0+) where apparently practically no spring grain is grown. Intermediate figures in parentheses are our rough estimates, discussed in the text.

COMPETITION AMONG GRAINS

TABLE V.—AVERAGE ANNUAL NET EXPORTS OF FIVE GRAINS, BY COUNTRIES AND FIVE-YEAR PERIODS, PREWAR AND POSTWAR*

(Million cents)

Grain and country	1909-10 to 1913-14 ^a	1925-26 to 1929-30 ^b	1932-33 to 1936-37 ^a	Grain and country	1909-10 to 1913-14 ^a	1925-26 to 1929-30 ^b	1932-33 to 1936-37 ^a
Total ^c	767.5	763.8	608.5	Barley	111.3	74.4	42.6
Wheat ^d	407.1	456.8	321.7	United States... ..	3.8	15.3	0.4
Rye ^d	47.6	26.3	23.1	Rumania	16.8 ^d	14.5	9.7
Barley	111.3	74.4	42.6	Canada	2.5	13.8	4.5
Oats	53.6	27.2	18.0	Argentina	0.3	9.4	8.4
Corn	147.9	179.1	203.1	USSR	72.0 ^b	8.0	7.4
Wheat ^d	407.1	456.8	321.7	Algeria, Tunis.. ..	3.8	4.3	0.5
Canada	56.9	184.0	123.2	Poland .....	...^k	3.4	5.7
Argentina	50.0	94.4	82.8	Czechoslovakia.. ..	...^k	2.4	1.5
United States... ..	64.2	90.9	-1.3 ^e	Chile	0.5	1.4	1.2
Australia	31.9 ^f	49.7	64.5	Hungary	4.1 ^g	1.2	0.6
Hungary	12.3 ^g	13.9	10.9	Australia	-0.1 ^e	0.6	1.3
USSR	104.6 ^b	6.6	10.4	British India... ..	5.1	0.1	0.2
Yugoslavia	7.1 ^d	6.3	3.0	Turkey	2.4	... ^k	1.2
Rumania	42.8 ^d	3.9	5.8	Rye ^d	47.6	26.3	23.1
Algeria, Tunis.. ..	3.2 ^j	3.7	7.6	United States... ..	0.5	7.7	3.2
Poland .....	...^k	1.7	2.3	USSR	17.3 ^b	4.4	2.6
Bulgaria	3.8 ^d	0.9	2.0	Canada .....	...^k	3.7	1.4
Chile	0.5	0.5	0.0	Hungary	8.8 ^g	3.5	1.8
British India... ..	29.8	0.3	2.3	Poland .....	...^k	2.6	10.0
Turkey .....	...^k	-1.3 ^e	1.4	Argentina	0.2	2.5	3.4
				Germany	14.3 ^m	0.9	-1.2 ^e
				Rumania	4.7 ^d	0.6	0.6
				Bulgaria	1.1 ^d	0.3	0.1
				Yugoslavia	0.7 ^d	0.1	0.0

* Data mainly from various issues of *International Yearbook of Agricultural Statistics*. With some exceptions (e.g., French Morocco), only very unimportant exporting countries have not been included. Except as otherwise specified, the averages are for August-July years. Under each grain the countries are arrayed in the order of net exports in the 5-year period ending 1929-30.

TABLE V.—Continued

Grain and country	1909-10 to 1913-14 ^a	1925-26 to 1929-30 ^b	1932-33 to 1936-37 ^b	Grain and country	1909-10 to 1913-14 ^a	1925-26 to 1929-30 ^b	1932-33 to 1936-37 ^b
Oats	53.6	27.2	18.0	Corn	147.9	179.1	208.1
Argentina	13.6	9.3	8.5	Argentina	64.8	123.5	154.4
United States...	1.4	5.6	-0.7 ^c	Rumania	36.4 ^d	17.1	15.6
Canada	5.2	4.6	3.2	United States...	21.7	12.1	-16.7 ^e
Germany	-1.2 ^f	1.4	-0.9 ^f	U. of S. Africa..	2.1	10.7	6.7
Chile	0.8	1.2	1.1	Yugoslavia	10.7 ^d	4.8	10.9
Rumania	5.9 ^d	1.1	0.5	Neth. Indies	0.7	2.7	2.8
USSR	23.7 ^h	0.8	1.9	USSR	6.6 ^h	2.1	1.1
Czechoslovakia..	... ^h	0.8	1.0	Bulgaria	4.2 ^d	2.1	1.9
Algeria, Tunis ..	2.2	0.3	0.4	Hungary	0.7 ^f	2.0	-0.2 ^e
Hungary	0.8 ^g	0.7	0.3	Indo-China	0.0	2.0	9.7
Eire .....	...^h	0.5	0.0				
Poland .....	...^h	0.4	1.1				

^a Mostly calendar years 1909-13.

^b For corn, averages for calendar years 1926-30 and 1933-37.

^c Approximate total, without deduction of net imports. As the character of the components indicates, the totals are not very satisfactory, but they are broadly comparable.

^d Data on wheat and rye include flour converted to grain; 75 per cent has been assumed to be the usual extraction coefficient.

^e Net imports, not deducted in arriving at totals.

^f 1910-14.

^g Adjusted estimate of exportable surplus for present boundaries as given in L. G. Michael, *Agricultural Survey of Europe: Hungary* (U.S. Dept. Agr. Tech. Bull. 160, January 1930).

^h Adjusted estimate for present boundaries.

ⁱ Adjusted estimate of exportable surplus for present boundaries as given in L. G. Michael, *Agricultural Survey of Europe: The Danube Basin—Part 2, Rumania, Bulgaria, and Yugoslavia* (U.S. Dept. Agr. Tech. Bull. 126, October 1929).

^j Algeria only.

^k Data not available.

^l 1909-12.

^m Adjusted estimate of exportable surplus for 1937 boundaries as given in L. G. Michael, *Agricultural Survey of Europe: Germany* (U.S. Dept. Agr. Bull. 1399, May 1926), p. 41.

TABLE VI.—PRODUCTION AND NET IMPORTS OF FIVE GRAINS IN MAJOR IMPORTING COUNTRIES OF EUROPE, BY YEARS, PREWAR AND POSTWAR*

(Million centals)

Crop years	Wheat			Rye			Barley			Oats			Corn		
	Production	Net imports	Total	Production	Net imports	Total	Production	Net imports	Total	Production	Net imports	Total	Production	Net imports	Total
PREWAR*															
1903 04.....	669	262	931	384	25.8	410	250	76.9	327	494	27.8	522	174	112	286
1904 05.....	588	272	860	382	16.5	398	221	71.0	292	433	46.5	479	121	114	235
1905 06.....	627	290	917	389	27.1	416	227	73.0	300	435	57.3	492	159	126	286
1906 07.....	695	264	959	389	21.2	410	258	77.4	336	501	28.4	529	185	132	317
1907-08.....	641	239	880	376	15.7	392	250	71.2	321	537	21.2	558	185	107	292
1908 09.....	631	237	868	418	2.4	420	237	86.0	323	490	35.5	525	182	93	276
1909 10.....	668	284	952	443	8.8	452	276	98.1	374	571	42.8	614	197	94	291
1910 11.....	609	327	936	411	21.6	433	211	119.5	360	505	57.1	562	215	129	344
1911-12.....	706	271	977	419	7.9	427	265	113.1	378	515	45.4	560	175	117	292
1912 13.....	671	324	995	438	6.4	445	260	97.0	357	530	52.2	582	204	168	372
1913-14.....	685	311	996	422	8.2	430	280	121.9	402	586	34.6	621	200	136	336

* Data from International Institute of Agriculture Yearbooks and Monthly Crop Report and Agricultural Statistics. It is important to observe that the figures are not comparable between prewar and postwar periods (1) because of boundary changes and (2) because the areas covered are otherwise not identical. Thus the prewar figures include Portugal and Spain, which are not included in the postwar data, while Estonia, Finland, and Greece are included in the postwar figures but not in the prewar. The prewar figures include also Austro-Hungary as a unit, whereas postwar data include only the principal deficit regions of the former empire, Austria and Czechoslovakia.

* For crop years August-July.

* Covering Austro-Hungary, Belgium, Denmark, Germany, France, Great Britain and Ireland, Italy, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland.

Crop year ^a	Wheat			Rye			Barley			Oats			Corn		
	Production	Net imports	Total	Production	Net imports	Total	Production	Net imports	Total	Production	Net imports	Total	Production	Net imports	Total
	POSTWAR ^a														
1924-25.....	407	360	767	230	30.2	260	170	48.1	218	416	29.8	446	81	122	203
1925-26.....	512	312	824	309	22.3	331	187	61.5	249	436	36.2	472	86	142	228
1926-27.....	421	384	805	249	31.7	281	177	74.3	251	474	20.7	495	86	186	272
1927-28.....	465	380	845	265	28.9	294	183	67.0	250	453	19.0	472	72	188	260
1928-29.....	506	371	878	312	11.9	324	214	70.3	284	484	16.3	500	53	163	216
1929-30.....	542	297	839	305	14.3	319	213	85.5	299	509	14.6	524	78	149	227
1930-31.....	450	364	814	289	26.2	315	188	86.2	274	420	33.1	453	90	181	271
1931-32.....	493	354	847	252	35.5	287	186	63.9	250	431	26.9	458	68	260	328
1932-33.....	596	264	860	318	22.7	341	205	46.1	251	475	17.2	492	90	191	281
1933-34.....	676	233	909	330	15.9	346	204	57.5	262	495	17.2	512	79	161	240
1934-35.....	593	212	805	293	15.9	309	193	47.6	241	418	19.6	438	95	158	253
1935-36.....	600	212	812	285	15.7	301	198	47.6	246	412	13.9	426	79	165	244
1936-37.....	508	257	765	266	17.0	283	190	47.4	237	408	13.4	421	96	202	298
1937-38.....	578	231	809	265	19.0	284	203	47.8	251	432	12.1	444	108	215	323
1938-39.....	602	247	939	316	18.2	334	242	48.3	290	481	10.7	492	98	159	257

^a Covering Austria, Belgium, Czechoslovakia, Denmark, Eire, Estonia, Finland, France, Germany, Great Britain and Northern Ireland, Greece, Italy, Netherlands, Norway, Sweden, Switzerland.

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