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CONTENTS

INTRODUCTION	vii
CHAPTER	
I. The Malthusian Bogey is Extinct!	13
II. Unfortunately, the Malthusian Bogey is Not Yet Extinct	30
III. When Agronomic Science is Bankrupt	49
IV. What the Agrobiologist Really Has	63
V. Delimiting the Population Problem	94
VI. Expanding the Primary Limit	123
VII. Peoples Beyond the Threshold:	167
Great Britain	
Italy	
Germany	
Japan	
VIII. The Price of Peace	244
APPENDIX: Crop Yield a Phase of the Mass Action Law	259

INTRODUCTION

THE PRIMARY object of this book is to furnish a scientifically based answer to the question: "What is the maximum number of persons who can exist on the produce of one acre, or one square mile, of arable land?"

This question is raised and answered because it touches the roots of some of the gravest problems that confront our present-day civilization.

The whole world is drifting into an era of nationalistic isolation in which nations are being forced to depend more on the natural resources under their own control, and less on international trade. The free exchange of populations (emigration) has practically ceased because all countries wish to reserve opportunity for work within their borders for their own citizens, and for the same reason they have built and are still building tariff walls to keep out foreign goods that can be produced at home.

The practical result is that densely populated nations, whose industrial workers have been living largely by the export trade, and also predominantly agricultural nations wherein natural increase in population has resulted in excessive crowding on an inadequate extent of arable land, now find themselves without outlets for their surplus numbers, with van-

ishing foreign markets for the products of their industries, and with restricted opportunities for obtaining needed raw materials and food. Out of these situations there has developed, and is further developing, a pressure of population that, if history repeats itself, must result in armed conflicts.

With this parlous state of the world as a background, this book is intended both as an exposition of man's new command over the boundless riches of the vegetable kingdom and an argument as to how distressed nations might use this command to relieve their situations. The argument is that if all nations provided themselves with adequate agricultures, so that each and every one of them could with ease obtain from its own soil all the food and agricultural raw materials essential for a comfortable national existence, the pressure of population that has now mounted alarmingly in many quarters would greatly abate. The necessity—and certainly the justification—for new wars to gain access to desperately-needed means of livelihood for straitened populations would be eliminated.

In this sense it is argued that the surest means for promoting international peace, and for minimizing if not for abolishing the plague of war, lies in the improvement of agricultural production to such an extent that nations may live at home, unmenaced by starvation or even privation; and independent, if need be, of foreign sources for the things that are really material to human comfort and well-being.

Aside from the argument, the book is an exposition

of those newly-recognized fundamentals of plant biology out of which the agrobiologists, developing the lead opened by Mitscherlich twenty-six years ago, have constructed a new science of crop production that not only conforms to the definition of an exact science, but has also expanded the potentials of food production far beyond the most extravagant imaginings of the old agronomy.

The reader will experience little or no difficulty in fitting argument and exposition together. If it is true that pressure of population on the soil is one of the major predisposing causes of war, and if it is true that the new agrobiolgy offers a means of relieving this pressure, then it should be the first business of a world desperately in search of a formula for peace to square its agriculture and its agrarian polity with the new realities of science.

Chapters I to III contain a discussion of the origin and the consequences of pressure of population on the soil. In these chapters occasion is taken to dispel an illusion that has warped contemporary viewpoints on the population problem. This illusion is that Malthusianism is a spent force, and that increase of population cannot now overtake the supply of the means of existence. The fact and the truth are that population has already overtaken the supply of the means of existence in certain sectors, resulting in the accumulation of dangerous pressures that only doubly or trebly productive agricultures can relieve.

In Chapter IV opinion and argument are laid aside and an examination is made of the scientific bases

on which the new agrobiolgy has been erected, and in Chapters V and VI the data of agrobiolgy are used to find the relations that disclose the quantitative limits within which the population problem can be solved. In other words, a measure is taken of the limit ratio between population and area of arable land, thus arriving at an answer to the question raised in the beginning.

Viewed merely as a definite accretion to established knowledge, the new systemology of plant life uncovered by the agrobiologist has an enduring intellectual value in itself; when applied to man's greatest problems it becomes intensely vital from the practical standpoint. In Chapter VII the theme passes from the general to the particular. The needs of specified nations that furnish typical examples of oversaturated populations are measured against the means available to them for escape from situations that are dangerous not only to themselves but also to the world at large.

In Chapter VIII there is a return to opinion and argument. In general, it boots little to possess even the finest tools if they are not sapiently used. The new agrobiolgy offers itself as an implement whereby men may carve a new, a safer and a more splendid existence; but it is undeniable that a vast accumulation of social-economic and political rubbish must be cleared away before the new tools can produce results. The population problem is not by any means exclusively a production problem; it is equally, and perhaps more formidably, a problem of social-

economic reorganization. The author has some ideas on the subject, which are offered for what they are worth.

The book closes with an Appendix wherein have been gathered those details of agrobiological calculations which it has been deemed advisable to spare the general reader, but should be included to satisfy those who care to make an effort to understand the mathematical language of agrobiology, which on the whole is fairly simple.

RIDGEWOOD, N. J.

Chapter I

THE MALTHUSIAN BOGEY IS EXTINCT!

UP TO about ten years ago the Malthusian vision of a world that would eventually be saturated with population was still much alive to disturb the minds and stir the pens of the social scientists, the students of population, and all others who could find time to think about the future of the human race.

Malthus, it will be remembered, was the Englishman who first dramatized the fact that human beings tend to multiply. He pointed out that a steady growth of population will not necessarily result in either public or private inconvenience *if* the means of existence are multiplied in like proportion, but that if population outruns the production of food and the other essentials of life some of the individuals composing the body politic will be left in the lurch. As in his time (1798) Malthus surveyed the situation, England, for example, was a relatively small country containing a certain definitely known number of acres of land on which food might be raised; the productivity of this land was limited and could not be increased indefinitely, because even the best arts of the farmers could not coax more than a certain

amount of produce from an acre of soil. On the other hand, the population of England and other countries was increasing from year to year. From consideration of these two facts—a fixed area of land and a constant increase in the number of people to be fed from that land—it needed little gift of prophecy to foresee that the number of people must eventually become so great as to overtax the available resources of food.

It was also clear to Malthus that serious consequences would begin to make themselves felt even before the land became fully saturated with people. The supply of food not being capable of enlargement while the number of individuals to be supported continued to mount, the average pro rata share of each individual in this supply must gradually be reduced. The economically weaker members of the community, he said, will bear the brunt of this growing shortage, and they will gradually sink through various degrees of privation, malnutrition and hunger, becoming more and more an easy prey to disease, pestilence and the other concomitants of extreme poverty. Finally, when the supply of food becomes definitely insufficient to sustain all, famine and actual starvation of some must ensue, especially in years of short crops. In this last stage it would be a sheer impossibility for the population to increase further; the death rate must then match the birth rate.

The views of Malthus attracted much attention from his contemporaries and even down to the present time, not only because of the gloomy picture he drew of the impending fate of humanity, but equally

because of the means he proposed for evading this fate. As he saw the matter, there was no possibility of increasing either the area or the productivity of the available tillable land; hence, in that direction, humanity was definitely walled in. On the other side, relief from the threat of an inordinate increase in population might be had from what is known as birth control. No more children should be brought into the world, said Malthus, than might be reared in comfort; and thereby he provided a subject for discussion that is still far from exhausted.

As was remarked in the beginning, the Malthusian theory of the tendency of population to increase to and even beyond the means of existence has been generally pointed to as a fair promise of what was in store for the human race. Certainly it could not be gainsaid that the area of cultivatable land on this earth is limited and humanly incapable of enlargement; and it was equally impossible to deny that if population continued to increase at the accustomed rate there must sooner or later come a time when the land could not feed the people. Even as late as 1925 the students of population were devoting much effort to forecasting the time when the final stage of saturation would be reached, and they had—or thought they had—some very definite figures to work on. The geographers have estimated that the total area of land surface of the globe is about 33,000 million acres, and the same authorities are in some agreement that about 40 per cent of this area, or say 13,000 million acres, is susceptible to a more or less intensive

cultivation. On the other hand, the population of the earth at that time was about 1,700 million and, among the white races at least, was increasing at a rate of about one per cent a year. The dark races were increasing at an unknown rate which was perhaps something less than one per cent in such regions as India and China, where past fecundity had already brought about many of the conditions prophesied by Malthus for the English and other white peoples if they did not heed the writing on the wall.

The arithmetic employed by the latter-day prophets of Malthusian saturation is quite simple. Assuming that, as of 1925, the population of the globe is 1,700 million and that the average rate of increase is one per cent a year, it is easy to compute, by the principle of compound interest, a table that will show the number of people on the earth at successive fifty-year periods. See Table I.

TABLE I.—THEORETICAL INCREASE OF POPULATION

<i>Year</i>	<i>Population in Millions</i>
0	1,700
50	2,796
100	4,598
150	7,562
200	12,437
250	20,455
300	33,640
350	55,326
400	90,991
450	149,647
500	246,144

Around these two sets of data—area of land and rate of population growth—Professor East published a book under the title *Mankind at the Crossroads*, which was perhaps the expiring gleam of old-style Malthusian prophecy. An accomplished biologist, Professor East could assert that there is no evidence whatever of a progressive decrease in the fecundity of civilized peoples, and that as to them the mathematical basis of Malthusianism is still firmly seated; and also having had a close contact with practical agriculture in the United States, he could prove that under contemporary agricultural conditions it requires 3.2 acres of land to feed one average individual for one year at an American standard of living. In other countries, where the density of population is greater, and where agriculture is more intensive, the ratio is about one person to each two acres when the standard of living is calculated on an American basis.

From data such as this Professor East, making allowances for what increases in the productivity of land could then be foreseen from the visible resources of ordinary agriculture, reached the conclusion that the saturation limit for the world's population would be attained when there is one person for each 2.5 acres on 40 per cent of the land area of the globe. This gives a figure of 5,200 million people, and it needs only a brief reference to the Malthusian multiplication table to show that at the assumed rate of increase this figure would be reached in just a little over a century. And these 5,200 million people, he

said, must be content, on the average, with the limited dietary and the few material necessities now enjoyed by European peasantry. This day was not so very far distant, and Professor East could remark that babies now living (1925) might be alive to witness its arrival.

Considering the United States specifically, Professor East found that the area of cultivatable land is between 800 and 900 million acres, not all of which can be equally fruitful; and striking a balance between the best and the poorest land, the upshot is, or was, that not more than 160 million people could be maintained in comfort on the products of the soil of the United States. Similar considerations would apply to other portions of the earth inhabited by the white races, and in view of the apparently rapid approach to the limit of saturation, Professor East could well picture "man at the crossroads of his fate." Like Malthus, East saw no escape from ultimate saturation except in a sufficient lowering of the birth rate.

About the time that East was re-dimensioning the Malthusian concept to fit the conditions of ten years ago, the statisticians were undermining his major postulate, which was that population is increasing and must continue to increase at the rate of about one per cent a year. Among these was Professor Pearl, who discovered what appeared to be a new mathematical law of population. The mathematical details of this law need not concern us here, but it amounts to this: when a nation of people have adjusted them-

selves to a certain national environment, as was the case with the United States at about the beginning of the past century, the population increases slowly at first, then more rapidly until the rate of increase reaches a peak, after which there is a gradual decline in the rate until the increase becomes small again. The curve of population, as worked out by Professor Pearl, has the shape of an old-fashioned letter *f*. At the time Pearl was making his studies the population growth of the United States had somewhat passed the steep middle portion of this *f*-curve and was entering the flattened upper portion. Knowing the characteristics of the lower portion of the *f*, it was possible to calculate the still unattained upper portion. By this means it could be predicted that the United States will have 149 million inhabitants by 1950 and 185 million by the year 2000, after which the annual increase will be quite moderate. So far as the data available to Pearl went, it appeared that a similar law of population applies to other countries. At any rate, the mathematics of Pearl, if valid, appeared to show that the population of the United States will be self-limited to somewhat less than 200 millions within less than three-fourths of a century.

Still, in view of East's conclusion that if the American standard of living continues to be based on 3.2 acres of fairly good land per person the United States will reach a condition of saturation when it has 160 million inhabitants, the 185 millions figured by Pearl would mean a reduction of this standard unless means were found to cover the shortage by exports of manu-

factured goods in exchange for foreign agricultural products.

However, it was not long until further and more searching study by the statisticians upset the beautiful symmetry of Pearl's curve. It has lately transpired that population statistics, like many another raw material, have to undergo a refining process before the true values contained in them become available; in population studies it is now necessary to distinguish between "crude birth rate" and "net reproduction rate." If attention is fixed on the crude birth rate in connection with mortality figures the populations of nearly all countries will appear to be steadily increasing. But if the net reproduction rate is taken into due consideration it will be found, according to Kuczynski and others of the modern school of population experts, that the populations of the principal industrialized and urbanized countries, such as Germany, England and Wales, Belgium, Sweden, France and the United States, are only apparently increasing; in these countries the real net reproduction rate is declining in such proportions that, if the decline is continued at the present observed rate, there will soon be more deaths than births and population will begin to diminish. Applied to the United States, the calculations show that the population of this country will barely reach 165 million by about the year 1960, whereupon the tide will turn and an actual decrease will set in.

The present best opinions of the experts regarding the course of population changes in the United States

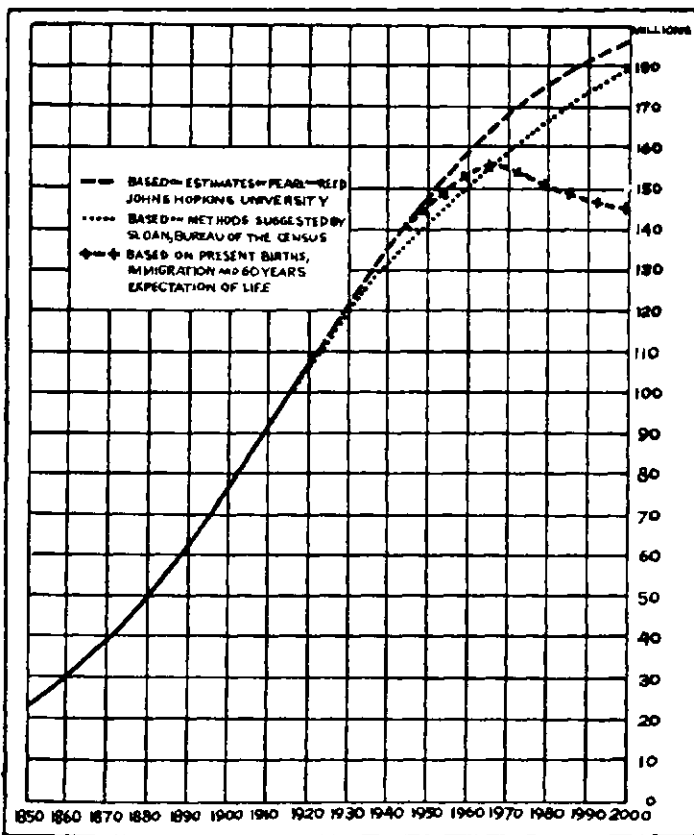


FIGURE 1. POPULATION OF THE UNITED STATES 1850-1920 AND ESTIMATES OF POPULATION 1930-2000 A.D.

are mirrored in Fig. 1, for which we are indebted to O. E. Baker. Of the three curves here shown the latest in date is the one that reaches a peak and then bends downward. If this curve be regarded as the one nearest the truth, this country can expect a maximum of

close to 160 million people, which is about the number that, according to East's figures, can be supported from domestic produce at the present standard of living.

From all of which it is now concluded that in the chief centers of civilization the people, whether they have ever heard of Malthusian saturation or not, are consciously or unconsciously following the suggestion made by Malthus and are restricting their increase. Not much is known as to whether the Russians and other peoples of Europe have entered the same path. Still less is known about the Orientals and other dark races except Japan, where the rate of increase is still something over one per cent and shows little or no sign of abating.

The point is that so far as it concerns us—the author and the reader of this book—the population experts have concluded that, as regards much if not most of the white race, the danger of Malthusian oversaturation is definitely removed, and there is a disposition to regard the specter raised by Malthus as having definitely been laid. The concept of a world overcrowded with people because of a continuing excess of births has rather given place to forebodings of a world on the way to depopulation by a decline and—who knows?—an ultimate cessation of human reproduction.

But suppose that the statisticians by some small chance should find themselves mistaken; suppose that the springs of human life in the Occidental world should again open up and pour forth an undimin-

ished or even enlarged flood of new human beings, would the ghost of Malthus then stalk forth again?

Not necessarily, say the agrobiologists.

As we have already remarked, the attainment of Malthusian saturation of population depends on the conjunction of two basic conditions. The first of these is that the number of people continually increases, and the other is that the means of existence are not subject to expansion. *Per contra*, the extremest form of Malthusianism is avoided either if the population is kept from reaching the saturation point, or if the expansion of the means of existence keeps ahead of the expansion of population. Up to a few years ago it appeared that for avoiding Malthusian saturation humanity had only one choice—to lower its rate of reproduction, and it is clear that in some sections this is being done. The other alternative, that of increasing the productivity of land, has seemed in the main to be hopeless, first because the area of cultivatable land is limited, and second because the art of farming, by which is meant the art of inducing useful plants to grow, has seemed on the whole incapable of rising much above a certain dead-level of efficiency. As recently as 1925, when apprehension of the approach of Malthusian saturation was still gripping many students of population, even such an expert as Professor Bear of the Ohio State Agricultural College could not promise more than about a fifty per cent increase in the yielding capacity of the soils of the United States. This increase, he thought, might be attained by American

farmers through the use of improved varieties of crop plants and a more intensive use of fertilizers; and, at that, the American farmer would only be approximating the efficiency of European agriculture which to all appearances was as high as farming efficiency (from the standpoint of unit yields) could possibly climb, but which, as matters then stood, afforded no guarantee that either the United States or Europe could long avoid the day when native soils would fail to sustain the populations; for the balance of their food supply all these nations would have to depend on such alien sources as might be open to them.

But with the rise of the new science of agrobiologic dynamics astounding new prospects of an increased supply of food per unit of area of land surface were disclosed to view. The agronomy professors of ten years ago could point to a certain body of knowledge that might be described as agricultural science, but which in reality was little more than a crude empiricism. It was known that certain substances, called fertilizers, would promote the growth of plants, but very little was known as to how these substances acted on the plants, or what were the limits or possibilities of this action or how such action could be defined, guided, and controlled so as to develop all the latent potentialities of vegetable organisms. It was known that certain varieties of plants might be endowed with improved yielding power by breeding and selection, but although the plant-biological departments of all the agricultural colleges, experiment

stations and the universities had long been well staffed with geneticists, little was known, and less was suspected, as to the real dimensions of the power of life that resides in the plant species on which the human race depends for its sustenance and comfort. In a word, neither botanists, plant physiologists, geneticists nor agronomists had learned to define *quantity of life* as something in plants that might be measured, or to define this vital power in terms of the outer circumstances under which plant life is developed. No definite quantitative relation between the inner and the outer factors of plant growth being known, the agriculturists of those days could naturally see no farther than the ends of their noses; and when questioned by the students of population as to what they were prepared to do in view of the rising tide of Malthusian saturation, they had nothing better to promise than the traditional results of past and current rule-of-thumb practice that went by the name of agronomic science. How little comfort the philosophers of old-style Malthusianism got from the agronomists we have already seen; the best that Professor East could do was to obtain an estimate that the annual produce of 2.5 acres of average land is required to maintain one average person, if that average person will be content with the limited dietary and the few material comforts enjoyed by the European peasantry.

But after the agrobiologists had taken up the pioneer work of Mitscherlich and Baule, and had carried it to its logical conclusion, the fog of empiricism that has enshrouded agriculture and the practical nutri-

tion of plants from their most ancient beginnings was blown away. With the discovery of the inverse quantitative relation between the mineral contents of plants and their vital powers the growing of crops has become a real science, which means a mathematical science that deals with fixed and measurable constants of Nature; the life processes of plants become as subject to calculation and control as operations in a chemical factory or in a machine shop. But what is of chief interest in the present connection is that, in defining and measuring the maximum quantities of life that can reside in living plant species, the agrobiologists have achieved a measure of the maximum productivity of land. This means that they have found a true measure of the quantitative relation that subsists between quantity of plant life and quantities of the external factors necessary to support that life, so that by suitable application and control of the external factors the plants can be induced to give the last pound of yield of which they are inherently capable.

In other words, the agrobiologists have taken definite measure of the riches of the kingdom of Flora and have demonstrated that, by taking thought, men may push their production of food and agricultural raw materials quite up to the theoretical limit. And this limit is vastly higher than the best that traditional agronomy could ever promise. It is unnecessary here to go into details of the maximum productivity of land—we will return to the subject—and for present purposes the conclusion may be stated

that instead of insisting on 2.5 acres to sustain one person under the régime of traditional farming, not more than $\frac{1}{4}$ acre (and contingently much less) would be needed. Using that figure as a basis of calculation, it is evident that when the business of food production has been put into the hands of competent agrobiologists the earth could support 36 times the 1,700 million inhabitants it had in 1925; even if there were no slackening of birth rates, the advent of general Malthusian saturation may still be displaced to the far-distant future.

So the Malthusian idea of a saturated world is done away with. The two postulates on which it seemed so firmly and terrifyingly based have been destroyed, one after the other. First the statisticians took away one of its legs by their demonstration of declining reproduction rates and stationary or diminishing populations; and now the agrobiologists have taken away the other leg by opening up practically limitless sources of food and organic raw materials.

Then will the world henceforth not need to think any more about pressure of population on the soil, arising either from too many people to feed or not enough to feed them with?

On the contrary, the nations of the earth have seldom, if ever, had greater need to consider pressure of populations on their soils than they have in the present conjuncture. Though the onslaughts of the statisticians from the one side and the agrobiologists from the other have apparently reduced the Malthusian concept to a wreck, if the gloomy prophet should re-

turn he might salvage a great deal from the ruins, because what he really taught was a theorem which is rooted in that most ancient and ever-enduring rule of life—the struggle for survival.

A glance at Table II at the end of this chapter will show that not a few important nations are far from able to give each of their inhabitants the average produce of 2.5 acres which East and others, basing their calculations on the old agronomy, have agreed is necessary for a comfortable standard of living. This will appear from the last column of the Table, which gives the "relative coefficients of saturation" which have been computed as follows: the average number of acres per inhabitant of the country is ascertained, and divided into 2.5.

These coefficients may not be strictly accurate for such countries as Russia or China, but as regards the highly industrialized nations of Europe it is clear that if sole dependence were placed on produce of the native soils some of these nations would be forced to endure more privations than others, and some would find existence impossible. So far from being a played-out theory, Malthusianism in its worst phases is a stark reality in some of these regions, and in others it is staved off by undependable circumstances which will further engage our attention.

TABLE II.—RELATIVE POPULATION DENSITIES OF VARIOUS COUNTRIES

Country	Population (Millions)	Arable Land,		Relative Coeffi- cients of Saturation
		Million Acres	Acres Per Inhabitant	
Canada	10.3	300.0	28.9	0.08
Argentina	11.8	210.0	18.5	0.13
New Zealand	1.5	18.8	12.2	0.20
Russia	165.7	700.0	4.2	0.59
United States	125.0	413.2	3.3	0.77
Australia	6.6	21.1	3.2	0.78
Denmark	3.5	7.9	2.2	1.12
Spain	28.7	56.0	1.97	1.26
Yugoslavia	13.9	27.1	1.94	1.28
Roumania	18.0	33.3	1.85	1.35
Hungary	8.6	15.0	1.73	1.44
Sweden	6.2	9.5	1.54	1.62
Bulgaria	6.0	9.2	1.53	1.63
Poland	32.1	44.4	1.38	1.81
France	41.9	54.7	1.30	1.92
Italy	41.8	53.3	1.27	1.96
Germany	65.3	73.4	1.12	2.25
China	444.4	341.1	0.76	3.25
Czechoslovakia	14.7	10.8	0.73	3.39
Austria	6.7	4.7	0.72	3.46
Netherlands	8.0	5.5	0.69	3.62
India	351.4	228.1	0.65	3.85
England and Wales	40.0	25.3	0.63	3.97
Belgium	8.1	4.5	0.56	4.52
Egypt	18.6	7.8	0.55	4.53
Greece	6.4	3.2	0.49	5.00
Japan	66.3	23.9	0.36	6.94

Chapter II

UNFORTUNATELY, THE MALTHUSIAN BOGEY IS NOT YET EXTINCT

MALTHUSIANISM, rightly understood, is something more than an end-point, a terminus; it is something—a process—that has a beginning and a middle as well as an end. What the statisticians have proved—if they have proved anything—is that the end is not likely to turn out exactly as was at first expected. The flood of human life which threatened to fill all reservoirs and then overflow with disastrous results has shown signs of decaying and drying up. What has come into the minds of the average person when Malthusianism is mentioned has been a vision of some near or not very remote time when the world will be like a huge rabbit-warren; when there will be hunger on a grand scale; and when no new baby can be ushered into the world with any chance of survival unless its birth has been preceded by the death of some preëxisting consumer.

But before the earth or any part thereof could become 100 per cent saturated with population it must first pass through all the lower stages of concentration; the 100-per cent stage will be preceded by the 75-per cent stage, and this by the 50-per cent stage,

etc. It is easy to draw an eye-catching picture of the horror and misery that might afflict the world or a nation when the 100-per cent stage has been reached, but will the 75-per cent or the 50-per cent stages be wholly exempt from horror and misery? The statisticians have done well to show that the ultimate end-point will perhaps not be reached by some of the white races, at least. But having exploded one of the Malthusian concepts—and that one not the most significant, albeit the most spectacular—the public interest will hardly be served by an appearance of treating Malthus as a prognosticator whom circumstances have belied, because he is unable to make 100 per cent delivery.

It was from the writings of Malthus that Charles Darwin first obtained the hint that led him to a recognition of the struggle for existence that ceaselessly goes on among all forms of living things, and eventually led him to the law of the survival of the fittest and the doctrine of organic evolution. What Malthus saw about him was not merely the dismal end-point that has provided so much work and excitement for the population experts; what he actually saw was people involved in a struggle to live amid surroundings where the opportunities to work and to obtain the essentials of existence were limited, and as regards individuals were obviously becoming more and more circumscribed because of the growth of population; what Malthus saw was an intensifying competition for the products of a limited area of soil, a competition that was already imposing want and

hardships on individuals, whose misery would not be done away with even should the increase of population suddenly halt.

It was from Malthus that the political economists and the sociologists obtained their concept of "pressure of population on the soil." The use of the term "pressure" in this connection is not inept; it connotes something that tends to expand against an external restraint, like the body of a growing youth against a garment that has little or no capability for stretching. At the theoretical end-point of *that* process the garment must surely be rent, but not before the youth has passed through a season of deepening discontent accompanied by longings and endeavors to procure an easier covering. And suppose that such a youth should cease growing while his unyielding casing was still causing him a maximum of torture which he must thenceforth continue to endure without hope of relief. . . . Now apply this concept to a nation or other isolated section of humanity that has grown, not until it has taxed its resources to the very limit but up to a point where these resources have become inadequate to cover all its needs, to say nothing of its wants and desires. Will not such a group be prone to take into consideration any or all means that offer hope of improving its condition?

This is the residuum of Malthusianism which the statisticians have not destroyed and with which traditional agriculture is not coping successfully.

It is here that we must emphasize a concept that is too often overlooked in the prevailing fashion of

regarding Malthusianism as a dead issue instead of what it really is: the very heart of the population problem. As every one will agree, on reflection, there is little or no pressure of population on the soil where the means of living are abundantly available, as when a nation is producing an export surplus of food and agricultural raw materials. In this sense there is no population problem (as we understand it) in such lands as Australia, Canada, the United States, Brazil, Argentina or other regions where there is still a superfluity of arable land. For us, Malthusianism does not begin in any country until the relative coefficient of saturation, as defined at the close of the preceding chapter, has reached the value of unity. There may be room for difference of opinion as to the precise arithmetical basis on which this coefficient is calculated (we have taken unity as 1 person to 2.5 acres), but the essential point remains the same under any basis of calculation: a nation has crossed the *threshold of Malthusianism* when its population has increased just beyond the point where the land fails to supply the average inhabitant with a comfortable living. The farther the population has passed beyond this threshold the more parlous its situation; there may be an infinite gradation between the Malthusian threshold, where comfort begins to diminish, and the theoretical final end-point where there will not be enough to maintain all in even a miserable existence. The Malthusianism that concerns us in this book is *the present result of past birth rates*; what the statisticians may find out or imagine about current and

future birth rates is not of primary interest here.

Since this book is to be largely a discourse about one of the major phases of pressure of population on the soil, it is due the reader that we make it clear what is meant by pressure of population in general, how it originates, and how it manifests itself in that residuum of Malthusianism which the tabulating machines of the statisticians have not exorcised, and at which the agrobiologist may try his hand if he is allowed.

Without at first conceding anything to the statisticians, it may be observed that there was a time when the population of any region was small, and men lived as hunters and nomads, seeking game over a wide territory or moving their flocks from one grazing ground to another. As the primitive tribe increased in numbers its members intensified their hunting activities or enlarged the size or number of their herds. Pressure of population on the soil, meaning difficulty in obtaining the means of existence, did not begin until game became scarce in proportion to the number of hunters, or when pasturage began to be overgrazed; the tribe would then be forced to realize that it had outgrown its resources. Under the pressure of necessity it would seek to expand into other territory that was perhaps already tenanted by another tribe, and there would result one of those explosions which we know only too well as war.

When the hunting and pastoral stages were succeeded by the agricultural stage the ability of the land to sustain population was enlarged, but the process

of accumulating pressure on the soil remained essentially the same. At first only a relatively small area of cultivated land would be needed to support the population, and as numbers increased the new mouths to be fed could be accommodated by taking in more new land. It is obvious that in the case of a given nation or region this process may continue smoothly as long as there is new land to be taken in. But when all the good land has been occupied the inhabitants will be confronted with new alternatives. One of the simplest is for the excess of population to migrate to some other region where fresh areas of land may be occupied. If migration is inconvenient or impossible, relief from the increasing pressure of population may be had by enlarging the productivity of the land already in use. This will be a satisfactory means of relief as long as it works; if every acre of land were like unto the widow's pot of oil that flowed and flowed as long as empty vessels were brought to it, there would be no limit to the number of people who might find sustenance on a limited area of land. But so long as no Elisha of agriculture has arisen to turn the soil into an unlimited source of nourishment, men find that the plants on which they depend for food and raw materials are themselves held by their environments to limited possibilities of growth. The most that any system of farming can do will be to remove, as best it can, the factors that restrict the growth of crops. But when traditional agriculture has come to the limit of its resources in this matter the limit of food supply is reached, and with it a limit

to the pressure which the land will endure without an explosion.

What, then, is the state of a region or nation that has arrived at the point where its own acres just suffice to feed its people? If the theoretical end-point has been reached, the theoretical alternatives will present themselves; the population must be held stationary voluntarily or involuntarily. If voluntarily, the number of births will be restricted so that at least the number of births are not in excess of the number of deaths, and all may have some chance of survival. If births are not voluntarily restricted an equilibrium will nevertheless be imposed by inexorable circumstances. The too-many new lives that come into being by the free exercise of man's biologic power of reproduction will be ruthlessly snuffed out in the struggle for existence. Those best able to procure the necessities of life will continue to live, and the less fortunate will be engulfed in the consequences of undernutrition, the ravages of pestilence and disease, to which may be added hunger marches, infanticide, the slaughter of riots, and perhaps irruptions into or from neighboring territory.

There may be still a way out for the nation which has arrived at or is too closely approaching the Malthusian frontier (there are even now such nations) if it possesses resources other than agricultural. If it has iron mines or coal fields the surplus of people who cannot migrate or find employment, or be sustained by the produce of the home soil (England is such a nation), may turn their hands to the fabrication of

steel or employ coal as a source of power with which to manufacture clothing or other articles for use in countries still having a large excess capacity for food production. This is an excellent solution where—and for so long as—it can be resorted to. As long as it is satisfactory to all concerned, it is fitting that there should be an exchange between differently endowed portions of the globe; that England, for example, should receive the beef and grain of Argentina, the tea of India and the cotton of America in exchange for manufactured goods and other services. But the different sections of humanity are in a state of flux, and are all tending toward the same sociological base level. Evidence is piling up to convince attentive observers that differentials above or below this base level are being wiped out. The accumulation of an excess of population in one region, there to subsist because distant acres in the control of aliens still produce an excess of food, can justify itself only so long as those same distant acres are themselves undersaturated with population, or so long as distant populations are satisfied—or are permitted—to take the goods that mean food and life to those who have marooned themselves on an inadequate soil.

At this point the statisticians may be allowed to reiterate that the turning point has been reached; that there is now a negligible danger that the western civilizations will travel much farther toward the still distant Malthusian terminus; that instead of dreading the approach of overpopulation this civilization has reason for dreading the opposite tendency—a declin-

ing population that may go far toward national dry rot and what the late Theodore Roosevelt once dramatized as "race suicide." The statisticians may go on to ask whether, if populations stop growing while the Malthusian frontier is still afar off, will there not be enough for all? Consider (if only as a matter of statistics) the vast areas of virgin land in the Americas and elsewhere that yet remain to be exploited; if there are 13,000 million acres of arable land in the whole world, and if the population of the globe is stabilized at about 2,000 million, there will be an average of $6\frac{1}{2}$ acres per person, which should take liberal care of all necessities and even luxuries—if only there be invented some system for the equitable distribution of the produce of these acres. And what about this marvelous new agrobiology, of which we have already heard something, and perhaps will hear more? If all or even much of what is promised should be materialized, so far from requiring $2\frac{1}{2}$ acres to sustain one person, less than one acre should be required. There can thus be no question of the ability of the earth to support populations stabilized at the expected levels.

However, as a celebrated American politician once remarked, what now confronts us is a condition and not a theory. It may be granted that birth rates have slackened and that they may even slacken still more. But to the continual regret of all humanitarians, and especially to the regret of the statesmen of countries bordered by swollen and not particularly amiable nations, certain parts of the world have already al-

lowed themselves to get into a situation from which birth control will not save them—or relieve some of them from certain causes for worry. In this connection the temptation is great to remark that the populations of India and China are already sunk far into the depths of Malthusian misery, and that other important sections of humanity have progressed considerable distances toward the same destiny. It is indeed well if the peoples of the West have sensed their dangerous drift and are applying counter measures. However, the house is already on fire and partly burned up; the blaze may be prevented from causing further damage, but what remains will not be so comfortable a habitation. There are already too many people in Italy, Japan, Germany, Czechoslovakia, etc., to be supported in decency on the natural resources of those countries. Any nation that has to import, for any reason, a substantial portion of its basic food materials in order that its people may be adequately fed, has too many inhabitants. Whether a nation's birth rate is rising, falling, or stationary, its soil is oversaturated with people if there is not enough home-grown food to go around at a standard of living that meets the desires of the average inhabitant.

There will be some readers, no doubt, who will think that this conclusion seems to fly in the face of very obvious facts. Under certain conditions it will be unnecessary for a nation to produce all its own wheat, for instance. For what purpose, we may be asked, was the ancient business of international trade invented, if not for an interchange of goods between

nations? And indeed, is not the exchange of manufactured goods for agricultural raw materials now actively going on everywhere? As we have remarked before, from Argentina, a nation that feeds itself, beef crosses the Atlantic to England, a nation that does not feed itself; in return, hardware from England goes to Argentina in the same ship, and both nations are satisfied.

But international trade as now constituted is not an infallible insurance against pressure of population on the soil; it is, at most, an uncertain, precarious and, except under particular circumstances to be mentioned further on, a temporary recourse, subject to evanescence. International trade as a sure means of livelihood for a nation that cannot or does not live on its own agricultural resources depends, in the last analysis, on competitive ability in *all* the senses of the phrase. Since all purchases made in international trade must be paid for directly or indirectly by an exchange of goods or services, the food-importing nation must above all things be sure of its foreign markets. But foreign markets are hard to acquire, and may be lost in various ways. An underdeveloped or so-called backward nation which affords a good market for textiles may eventually put up spinning mills of its own; in that case the operatives in the original country of supply lose employment, and for sustenance are thrown back on the native soil which they left to find jobs in the mills. This is a case where population is pressed against its own soil by pressure originating outside the land that has overdeveloped

its industry. Quite similar in effect is the case where the goods of one nation are driven out of a foreign market by the goods of another nation whose workers are either more skillful or are willing to work for lower wages so that the goods they produce can be sold in the face of competition. In these cases pressure of population shows itself as something that can cross oceans and political boundaries. Where two industrial nations compete for the markets of a third nation the pressure they exert on one another may be described as indirect. But the population of one industrial nation may find itself exposed to direct pressure from another industrial nation that is trying to capture its own home market for goods that itself produces, thereby lessening the opportunities of the home workers for employment and throwing them back on the home soil. In this sense pressure of population may be likened to a universal fluid that bathes the whole earth, seeking to enter any unobstructed opening or unguarded crevice. This is the peril to which every nation is exposed when it has passed the optimum saturation point of its home acres. Not a few contemporary nations have already passed this point, the result of past fecundity and overweening industrialization; and whatever the statisticians may now discover about the present birth rates of these nations the fact remains that any reproduction, even if apparently below the net rate, can but add to the disequilibrium of their present populations.

It is quite true that international trade does not always involve depressing sociological consequences of

the kind we have under consideration. It is undertaken gladly on both sides when the products of the one are exotic to the other, as when the silks of Japan are exchanged for the cotton of the United States, or the coffee of Brazil for the wood pulp of Scandinavia, or the nickel of Canada for the wines of France, or the olives of Spain for the hops of Bohemia. Neither is there much room for objection to the entry of foreign goods when the home market for a certain commodity is inadequately supplied by home producers. Although the United States, for example, produces much of its own sugar, we are quite willing to allow Cuba to send sugar here on very favorable terms, under the explicit and well-understood condition that the Cubans admit a sufficient volume of American goods under the same preferential terms. Such exchanges are of the essence of the so-called reciprocity trade agreements, by which nations seek to create new outlets for the toil of their workers.

But the sad fact is that in the nature of things reciprocity agreements to exchange goods that are being produced on both sides are little better than ropes of sand and have often proved not worth the paper and ink required to reduce them to writing. They can seldom be kept, at least not for long in the face of internal pressure, and if not abrogated are subject to extinction by quotas, etc. The home producers may admit their present inability to fill the existing hiatus, but are apt to allege that this is because admission of the foreign goods prevents them

from employing their capital or labor in that direction. Even now the domestic sugar producers of the United States, having had the great satisfaction of kicking out the Filipinos, are building up political pressure by which it is hoped eventually to thrust the Cubans entirely outside the American tariff wall. The industrial capitalists and factory workers of the United States are quite unwilling to be sacrificed on the altar of a reciprocity that would admit French manufactured goods in order that American farmers may send wheat to France, and French farmers are fixedly set against the admission of American wheat in order that French industrialists may send manufactured goods to the United States. "The home market for the home producers" is everywhere and always the slogan, and by nobody is this slogan bellowed more loudly or more persistently than by American farmers and American industrialists alike, though either of these groups may be willing to improve occasions for sacrificing the other in its own interest. In the face of such blasts and counter-currents, reciprocity of trade in common goods is predestined, as history shows, to a painful birth and a short shrift.

It is undeniable that all nations are on guard to maintain the means of livelihood of their people while seeking to appropriate means of living in the possession of others. Practically no nations now welcome unrestricted immigration, for the unmistakable reason that the newcomers tend to diminish opportunities for employment and to lower the standards of living of the original inhabitants; and if the nations

do not welcome foreign goods that they could themselves produce, it is only for another form of the same reason; no one, unless it be a rabid free-trader, can fail to understand that, sociologically, there is essentially no difference between admitting labor in person and importing it in packing cases. In the face of these two phobias that dominate the whole international atmosphere, all racial and political groups are more and more becoming sealed compartments into which adventurous seekers of a better livelihood cannot penetrate, nor from which unfortunates may escape to a better chance. Pressure of foreign population is everywhere repelled and forced to accumulate on the soil of its origin.

The upshot is that whatever enticements may seem for the moment to dangle in international trade, no racial group can be reasonably sure of anything but its own home market and its own soil. If the soil is inadequate it must nevertheless incessantly try to send out, on the best terms obtainable, the products of the surplus labor of its people in exchange for the products of other soils. But what if it has not a sufficient quantity or variety of raw materials on which to base a sufficient export trade? Or if its goods cannot cross tariff walls except at ruinous sacrifices? Or if its foreign markets are captured by more powerful, more adept, or better situated rivals?

To whatever extent such conditions bear down upon it, the commercially defeated nation must withdraw in upon itself, its population bottled up by pressure from the outside and given over, by necessity,

to the practice of autarchy, a term that has lately been invented to describe the economy of a nation that is striving for self-sufficiency. Under autarchy the chief preoccupation is to find an *Ersatz*—a substitute—for some necessary or desirable article that is not produced at home, or not produced in sufficient quantity, and which cannot be imported because there are no foreign credits against which it might be paid for, the lack of foreign credits being due to the impossibility of selling exportable goods on the foreign markets. All sorts of makeshifts must be resorted to; an economic dictatorship is necessary to conserve and allocate what supplies are available. There is not enough wheat; then let what wheaten flour we have be mixed with potato flour. There is not enough butter; then let the butter we have be supplemented with margarine. There is a scarcity of home-grown wool, and we cannot buy wool from Australia because the Japanese are capturing our trade in cheap porcelains; then let woolen cloth be made so that it will carry a larger percentage of a lower grade of shoddy. Foreign leather is difficult to procure, because superior competition of Java and Cuba has forced us to curtail our exports of beet sugar; then let shoes be made partly of strong paper. Our subsoil is yielding little native petroleum; then keep imports of foreign gasoline down to a minimum by compulsory mixing of all motor fuel with a fifth of its volume of alcohol distilled from potatoes. And so on; the group that thought to live by exporting values added by its labor to foreign raw materials finds itself pressed against a

reluctant soil that cannot respond in full to all the demands made upon it. Poverty begins to pinch; Malthusianism in the apposite degree comes into its own.

Such is autarchy, which in many shallow opinions is a perverse manifestation of national egotism and pig-headedness. For some reason it appears to be easier to interpret the erection of tariff walls by a nation that proclaims its devotion to self-sufficiency as an exhibition of selfish nationalism and exclusiveness than as a defensive measure by a people that must protect what is left to it. In the lexicon of fabricators of futile reciprocity agreements and the myopic apostles of unlimited free trade, tariff walls are hateful artificial barriers to necessary intercourse and an affront against common sense. Do away with them, they say; let trade be unhampered and goods will flow, as though by gravity, to where they are needed, and advantage will accrue to all.

As we have before remarked, the simile of goods flowing in trade "as though by gravity" to where they are needed is a little too simple. It is true that, in general, Nature abhors a vacuum, but trade is peculiar in that it is not stirred by one vacuum; it will not move unless there are two simultaneous vacua, and these two vacua must be of different kinds. American cotton goes to Japan not merely because Japan, as regards cotton, is a vacuum, but also and necessarily because the United States is a vacuum as regards Japanese natural silk, which can flow in the one direction only if cotton can flow in the other. A

high vacuum as regards beef always exists in England, but there will be no flow of beef into England from Australia or Argentina unless there exist corresponding vacua in Australia and Argentina for goods originating in England. These duplex, mutually equilibrating vacua cannot be created by free trade, but must preëxist by reason of differences in the original endowments of the different regions. It will be as sensible for Germany and England to exchange kitchen cutlery or the United States and Canada to exchange the same grades of wheat as it would be for neighboring farmers' wives to exchange butter and eggs.

It will perhaps be natural for free traders to suggest that the solution will be for each nation to confine itself to the production of those things for which it has the best natural endowment and to receive in exchange the things which it is least fitted to produce. Here again it is a condition and not a theory that confronts us. There are indeed differences in the abilities of certain nations to produce certain goods, and it should hardly be necessary to say that the distribution of such goods always takes care of itself. But the bulk of the world's production is of goods that can be produced everywhere on nearly equal terms so far as natural facilities of some sort are available, and these facilities are already manned by populations whom it will be impossible to root up and transplant in any general geographic rearrangement of industries. In broad, politically homogeneous regions like the United States, it is easy for the auto-

mobile industry to gravitate toward Detroit, or for the textile industry to migrate from New England to the South. Shifts in industries mean either free migration of labor or stranded communities, and in the present status of international affairs there will be no migration of alien workers across racial frontiers. In the absence of possibility (even if it were desirable) of reapportioning working populations in a supposedly rational redistribution of industry, there is no choice for peoples but to remain in possession of what means of living they now have. The free-traders may as well reconcile themselves to the fact that universal free movement of commonly produced goods is sociologically, politically and economically impracticable.

Chapter III

WHEN AGRONOMIC SCIENCE IS BANKRUPT

A COMMERCIALY defeated nation, driven in on itself and reduced to the practice of autarchy, finds itself in a mono-vacuum so far as regards procurement of necessities and conveniences which it has heretofore been obtaining from alien sources. Its people must face privation and hardships and be on their guard against further deprivation by the operation of adverse trade balances and the scarcity of foreign exchange. Like any other defeated and hard pressed army the nation proceeds to intrench itself. On the inside of its wall there is need for the products of other lands; on the other side there is no need, or at least no welcome, for the things it could produce by the surplus of its labor. To its gates come foreign traders bearing goods that the besieged would gladly admit, but the gates remain shut. Why? Because the offered goods can be paid for, if at all, only by giving up, on ruinous terms, a disproportionate quantity of the home products. There is a limit to the *Schleuderpreis*—sacrifice price—which even a sorely pressed group can afford to take; the comfort that might be thus achieved on the one hand will not compensate

the losses and sacrifices that must be made on the other hand; the population would be pressed still more heavily against its soil.

If the matter were ended thus simply by the reduction of commercially marooned groups to passive defensive attitudes, this writer would not feel quite the same urge to produce the present volume. But passivity is not an outstanding trait of most of the human family. The principal desire of most civilized men is not merely to live but also to live well; and if there is one thing the average man detests above another, it is to have the level of his comfort or standard of living forcibly reduced. Men and nations are naturally impelled to efforts to enlarge their assets by producing all they can sell, and if there is difficulty in selling in their usual markets they endeavor to press into new fields of trade and to entrench themselves there. But there is competition everywhere, both from other outside producers seeking to control the same markets, and from the native producers; the outsiders strive to vanquish each other by a contest in cost reduction or price cutting, and the native producers defend themselves by erecting tariff walls. Since foreign markets are hard to acquire and are subject to loss, means for establishing firm holds on them come in for close consideration. A favored method is the acquisition of colonies or dependencies whose fiscal policies and public expenditures can be controlled in the interest of the producers of the "metropole," or mother country. From such spheres of influence it is possible, by political leverage, to dislodge or exclude competitors

who could not be vanquished on the basis of selling price or service. We see this system at work every day. Another powerful motive for establishing holds on outside regions is the desire to make sure of sources of raw materials, exempt from foreign control, so that home industries may have the unhindered where-withal to make goods for the home market and foreign customers; control of iron mines, coal fields, oil deposits, fishing grounds, etc., are especially desirable. But control of colonies or dependencies is now seldom to be had, except by force, and cannot be kept except by force, because in the first place the colonies or "possessions" seize the first opportunity to achieve independence, and in the second place other nations equally athirst for controlled markets and sources of raw materials stand about ready to snatch them from hands unable to defend them.

"You want colonies?" asked Nietzsche of the Germans; "then take Holland, and the Dutch Indies will fall into your lap!" How often have we not seen the like done, attempted, or threatened in the not remote past!

So the nations that have colonies or dependencies arm themselves to defend both their home territories and their outlying possessions; and other nations that do not have colonies or dependencies arm themselves ostensibly to avoid being reduced to dependencies, but hardly less obviously for the purpose of improving the first opportunity of acquiring near or remote dependencies or to recover territory of which they have been raped. And what is not being done under the

plea of pressure of population! There was Japan, for example, undergoing social strangulation in her narrow islands by reason of a high and undiminishing birth rate which explains, if it does not excuse, her undertaking to assure the future comfort of her people by seizing Korea at the expense of a war with Russia. She has followed that up by dominating Manchoukou, where the familiar process of dislodging non-Japanese trade is visibly in operation. She is further suspected of a design to establish a fence around the whole Chinese region as a market reserved for her teeming industrial population, hoping perhaps that the white traders (and their industrial populations back home) will not take too much to heart their coming exclusion from this valuable field. Italy expelled the Turk from Tripoli in the hope of providing an overflow for surplus Italians who were having difficulty in subsisting at home; she is pressing France for a larger share of northern Africa, and is under suspicion of schemes to enlarge her Red Sea colonies at the expense of the Abyssinians. The Germans under the Kaiser, faced with a growing industrial population that German soil was not wholly feeding, built a great war fleet and are said to have instigated the Great War in the hope of breaking the ring that was keeping them out of rich colonial markets and sources of raw materials. On the other hand the British are said to have been the more willing to join in the fight against the Germans in order to prevent the rupture of their lines of communication, which the German fleet was being created to sever.

The most obvious of facts in the field of international relations is that the nations live in constant fear and watchfulness each of the other, and that no sure formula for maintaining peace has been found. Meanwhile they put as much effort as they can into preparations for war, and spend a vast amount of wealth in the acquisition of means of offense and in the construction of elaborate systems of frontier defense. Nonaggression pacts are being signed or negotiated, but preparations for another and a greater Armageddon go on unslackened.

And if war comes, what will be the assigned reasons? The assigned or ostensible reasons may be various, but when dissected the causes of all wars may be traced back to perhaps not more than two fundamental reasons, and these two might be reduced to one. A nation may fight if impairment of its sovereignty is threatened, meaning loss of control over persons, things or lands within its territory, or to protect interests or equities it holds beyond the home land. On the other hand a nation may hazard a war to gain possession of the territory or colonies or trade of another nation, though of course such ambitions are always cloaked with the best possible appearance of legitimate grievances. Sometimes a nation will go to war for offensive-defensive purposes, as when a war is precipitated because one nation is obviously gaining strength that would enable it to dominate or threaten the other nation's territory or vital interests, such as lines of communications with distant markets or sources of essential raw materials. A nation that enters

or prepares for conflicts of this sort generally avers that it is actuated by a motive to maintain a "balance of power" that will prevent the rise of another Napoleonism or a new Kaiserism. A more significant phrase is "preventive war" which has been heard in some recent not too well-guarded diplomatic conversations.

When reduced to its lowest terms and stripped of the sophistry by which it is sought to cloak the ulterior motive, the cause of war is the desire to gain or retain possession of something that is considered desirable or essential from the national viewpoint.* And when national viewpoints in this connection are critically analyzed it is observed that the bone of contention is mostly something that has a close relation to the national well-being in a material sense: enlarged resources of land or markets, these being the ultimate basis of a nation's competence to provide work, food and comfort for its citizens, particularly its industrial population who have no direct contact with the soil.

So, in the last analysis, war is found to be rooted mostly in pressure of population on the soil, the striving of peoples not merely to live but also to live well and better; and, as we have before remarked, this urge tends to become stronger when there is a considerable surplus of population that finds itself with-

* Many wars in the past have originated in dynastic ambitions or to promote the interests of small groups, but with the decay of monarchy, and as public opinion has become more vocal, war has tended to acquire a broader national character.

out a hold on the soil, and that is increasingly being denied suitable employment in industry and the export trade. There has been much prating about the capitalistic origins of wars; of industrial magnates and international bankers inciting, for their own enrichment, their governments to drastic action for the protection of old markets and the acquisition of new spheres of influence, but behind the magnates and the bankers, behind the governments themselves, there is generally the pressure of a mass of workers for whom work and bread must be found. Although the bankers and the magnates do not fail to take their rake-offs and their commissions, they are at least the paymasters (not faultless ones, perhaps) who distribute to the workers their share of the export operations.

War is unquestionably one of the major evils that afflict humanity; but, as Mark Twain once said of the weather, much is talked and nothing is really done about it. Peace conferences, disarmament conferences, naval limitation conferences assemble and disperse, leaving no substantial trace of their passage. A world court is set up, where the nations are invited to compose their differences, if they think these differences are of a nature that will admit of composition, but no nation will bring to this court the things it really has on its heart. An intensive search goes on all the time for formulas that will allay the dread and the suspicion that pervade and poison international relations. Personal hatred of war becomes an intense obsession of tens of thousands and even millions of individuals. Societies for the promotion of interna-

tional peace have ramifications throughout the world. Great religious denominations impose on their members a religious duty to renounce war for any reason, cause, or pretext, and they carry this renunciation to the point of refusal to handle arms even in the time of peace, besides prohibiting their ministers to serve as chaplains in the military services. Bellophobia affects all grades of society up to multimillionaires. A manufacturer who made a great fortune from high explosives left much of his money to provide annual rewards to individuals who are adjudged to have rendered distinguished service in the preservation of peace. A great ironmaster, whose products are indispensable in the fabrication of instruments of wholesale military devastation—tanks, battleships, 16-inch cannon—built a sumptuous palace to house an international court of arbitration, and left other millions to establish an institution especially charged with the function of thinking up reasons why nations should not spring at each other's throats. So far, this institution does not appear to have found anything better to do than to subsidize plausible individuals, mostly academicians, in writing and speaking and traveling back and forth across the seas to spread such sweet reasonableness as may be in them.

Yet in all this Babel of talk there are few signs that the ax is really being laid at the root of the upas-tree, or that the location of the root is perceived, even though it might be seen close to the surface. Pressure of population on the soil either is or is not a major cause of war; let those stand on the negative

side of that proposition who will. If pressure of population is a source of the world's major scourge, should not the crusade against war be directed against the source? If because of pressure of population peoples arm themselves so that they may be assured of their livings, and to be prepared for seizing opportunities for living better, will not peace be promoted if this pressure is substantially relieved?

Far be it from us to suggest that a formula could be found to satisfy all human longings for the comforts and the luxuries of life. But at least it can be suggested that the most might well be made of what is within reach; and there is much, even a great deal, that hard-pressed nations may take without war. It is time for pacifism to become pragmatic. Let war continue to be hated; even let tin soldiers and toy cannon be withheld from young boys, lest they become too much imbued with a war spirit. But above all things let intelligent pacifists become hard-headed realists. Let not quite so much reliance be placed in academic "promoters of international good will and understanding" whom a well-meaning philanthropism tickets from one country to another to delude themselves and others of like caliber that they are exorcising the war-devil. It would be hard to decide whether such conceptions as Ford peace ships and Carnegie peace endowments were more futile than fatuous. Futile they certainly are. All persons are grievously benighted who fail to perceive that nations already understand some things exceedingly well, who are not well aware that every nation wishes to

keep what it has, if not to obtain more of what is in the possession of others, and who fail to comprehend that nations wish by all means to avoid slipping into morasses of national poverty. No incantations of scholastic pacifism will quell or deflect national aspirations welling up from such depths. The men who will be the most effective in promoting peace will be those who best help their fellows to get what they need in peaceful ways. Let there not be so much preaching of "live and let live, bear and forbear," and more attention paid to pointing out the way of life and how nearly insupportable burdens may be lightened without thought of rapine.

Very well; where shall the new, pragmatic pacifism first begin to take hold?

Consider, at random, any typical European nation, say Czechoslovakia or Italy. Affecting both these countries there is found the same basic situation: a too-much-expanded population (the fruit of past increase), an inadequate agriculture, and a ring of none too sympathetic neighbors who have economic and population difficulties of their own. In past history the normal reaction of a Central European tribe to such a situation would be an irruption into surrounding territory in an attempt to displace or subjugate the original inhabitants. The human race may have lost some of the crude manners of a few hundred years ago, but he is a rash man who too easily assumes that human nature is not still essentially the same, or that the Czechoslovaks or the Italians, if their need became desperate enough, or if they saw a perfectly

good opportunity, would not at least take into consideration certain historically well-known methods that might lead to an improvement of their national situations.

It perhaps could not be maintained that every nation, having an adequate soil that provided all its people with a full sufficiency of the agricultural produce essential for existence, unmenaced by underprivileged or greedy neighbors, will eschew all warlike proclivities. But it will have less reason, certainly less excuse, if it could be shown that an appeal to the sword, besides being a gamble with death and misery, could in no event be more productive than a rational means already under its command, requiring nothing more arduous than the exercise of intelligence in directing the ordinary labor of its citizens.

Therefore the task of a genuinely constructive pacifism will be to bring to light those ways and means whereby nations may better their material conditions without committing or suffering the great wrong of war, to set these ways and means to fuller national lives in the foreground, and to insist upon their full consideration as alternatives to war. Is the saber rattled somewhere? Is there a demand for a wider place in the sun? Is there complaint that the homeland is too narrow, that the people are undergoing social strangulation because surplus populations have no place to emigrate and no market for their labor if they stay at home, that an unproductive soil cannot feed, clothe and shelter in decency the swarming masses? Is there, finally, a choice between

continued deprivation and a resolute assault on encircling barriers?

But before any swords are unsheathed, even long before the stage is reached when alarmed mediators begin to hover about, it should have been ascertained whether a nation that is complaining of inadequate resources, which it must allegedly compensate by trespass upon the resources of others, is making adequate use of the resources that it has; whether the native soil, which is alleged to be too niggardly to support even at a low level of comfort the millions who press upon it, might not really be capable of supporting three times as many millions at a level of comfort twice as high. There should be ready, beforehand, a clear picture of what such a nation might obtain simply by helping itself (with none to hinder) to what Nature has put within its easy reach, a picture which will be found so attractive as to force a comparison with the dangers, the inevitable sufferings and the possibly meager rewards of a war, victorious though it might be. The human animal is not always a reasonable creature, but unless men are swept off their feet by passion or frenzy they will, more often than not, take the line of least resistance and least danger, provided that the easiest way lies in plain view before them.

Here, as we conceive it, is or should be the program of a virile pacifism that might command respect and attention: to begin now to show the nations the line of least danger and resistance to possession of the basic things that underlie the essential well being of

their peoples. It may be too much to expect that *all* war will be abolished, but it is fairly certain that *some* wars, if they threaten to arise out of real necessity and not out of megalomania and lust of conquest for its own sake, might be obviated by prompting the necessitous potential aggressors to undertake, instead, a bloodless struggle with a not unwilling Nature. At any rate, and granting that the war-Hydra will be found to have many heads, a pacifism that would chop them all off must make a beginning with the first; and as good a beginning as any will be to show how peoples needing food and agricultural raw materials may have both in superabundance without having to brave the hazards of war.

This suggestion is offered in full view of the fact that there are numerous persons who are more or less imbued with the idea that no shortage of agricultural produce exists at all. The general food-producing capacity of the world is demonstrably far above what would be required to maintain every living inhabitant of the earth in more than comfort, and for such a reason many have been led to decry Malthus, and to comment on his inability to foresee the enormous expansion of the means of production since his time. It seems too easily to escape notice that this expansion has occurred mostly in regions in possession of groups of men who are not open-handed philanthropists, who have lately over-reached themselves by producing more than they can sell to those who have no real chance to buy, and who would rather destroy their superabundance than give it away. There is a glut of

agricultural products in the world's markets, and still there is no lack of privation in regions where need clearly overmatches supply, and where purchasing power does not exist. It might be maintained that there is more than enough—if only there were better distribution. But there is the rub, precisely. Better distribution is impossible so long as exchanges will move only in duplex vacua. One section has so much that scarcity is promoted by restriction and deliberate destruction, while in other sections the most strenuous efforts are inadequate to cover needs. There have come into being dangerous differences in economic and sociological potentials which no existing international apparatus can equilibrate. National poverty skulks glowering in the sight of alien, overflowing wealth, infallibly breeding the envy and covetousness out of which spring the conflicts that, whatever cloak may be thrown over them, hark back to pressure of population on the soil. This pressure is most dangerous where there are what we have called mono-vacua—eddies or pockets into which trade cannot flow in this kind of world. Such mono-vacua can be filled only by war or by increased domestic production. If it is not to be by war, then it must be by the new agrobiology, for the old, traditional agronomy is clearly bankrupt.

Chapter IV

WHAT THE AGROBIOLOGIST REALLY HAS

THE FOREGOING considerations land us on the conclusion that the task of maintaining peace among the nations depends in a very large measure on success in the neutralization (or perhaps we should say prophylaxis) of commercial mono-vacua or one-sided conditions of national need, those foci of national hardship and discontent wherein pressure of population accumulates and builds up until it must, and too often does, burst out into the flames of war. As we look around the world we will see that the most irritating of these mono-vacua are those in which there is a shortage of the products of the soil, mostly as regards the products that form the basis of a nation's food and clothing. This shortage exists first because the soil as a whole is too unproductive in relation to the number of inhabitants to be supplied, which is another way of saying that the traditional agronomic science is bankrupt; and secondly because the exportable goods that might be offered in exchange for the products of other lands find no satisfactory foreign market.

We feel again constrained to remark that, strange

as it may seem to some, what the human race—or at least large sections of it—desperately needs is a more productive agriculture. No person should allow himself to be blinded to this fact by contemplation of the huge surpluses that exist in some parts, and especially not by such bizarre proceedings as the burning of coffee in Brazil, the abandonment of sugar-cane fields ripe for harvest in Cuba, the plowing under of cotton and the killing of brood sows and little pigs in the United States, or by the convening of international conferences where Australians, Argentinians and North Americans try to persuade each other to cut down wheat acreage so that they may all charge higher prices to the rest of the world, and to their own compatriots at home as well. These maneuvers of nations with overgrown local agricultures should rather be considered for the additional difficulties which they throw in the way of filling the vacua wherein are being bred the storms that may again loose slaughter upon the world.

Now, if the new science of agrobiologic dynamics offers itself as apparently the sole means of filling, from the inside, these mono-vacua that cannot be filled from the outside, it will be natural for an interested world to inquire as to the competence of the new science for such a praiseworthy undertaking. Wherein, it will be asked, does agrobiology differ from the old, traditional agronomy, of which it is now alleged, with evident reason, that it is bankrupt in the sense that it cannot meet the demands made upon it by undersupplied peoples and commercially-de-

feated nations who are driven by painful necessity to the practice of autarchy? And how is the sudden apparition of this new science in such an old field to be accounted for? Ten years ago the nouns agrobiology and agrobiologist were still unpronounced, and have yet scarcely begun to be registered in the dictionaries. By what similitude of magic has the ancient art of tilling the soil—which numbers among its practitioners more tens of millions of men in all parts of the earth than any other single industry, upon which every government under the sun bestows a fostering care, and for the service of which thousands of experiment stations and agricultural colleges have been expensively equipped and manned by experts and specialists of all descriptions—been newly transformed into a vastly potent means of salvation for marooned groups and a war-threatened world? Undoubtedly the reader, in view of what hangs on the issue, is not likely to be satisfied with the *ipse dixit* of some more or less reputable authority, and will demand to see what the agrobiologist really has.

Here is, indeed, a matter not to be approached lightly. To hold out an illusive promise of means for mitigating the distress of nations, and to offer vain prospects of a lessening of the need or occasion for the holocausts of war, would amount to trifling with the time and patience of serious-minded people. The offered means must therefore be found to lie within the domain of reality. When it is asserted that the ancient art of agriculture, which is obviously failing to cope with situations that predispose men to new

outbreaks of destruction, has been rescued from empiricism and put on a sure and inclusive mathematical basis, the said basis should at least be made clear. And especially when it is claimed that the new science has definitely taken the measure of the riches of the vegetable kingdom and has found them unexpectedly and exceedingly vast, the common man may and probably will ask why and how.

It is therefore deemed appropriate to give here an account, understandable to the average intelligent general reader, of the origin of the science of agrobiologic dynamics, to describe in the plainest possible terms the basis from which it has sprung, and to indicate what its tangible content is. Such an exposition seems to be the more called for because, so far as the author knows, no adequate outline of the fundamentals of agrobiology has yet been written for perusal by others than experts.

The genesis of agrobiologic science is no different from the genesis of any other science; all real sciences, in fact, go through essentially the same process of being born.

Consider, for example, the science of chemistry as it was about the close of the eighteenth century. For ages, in fact before the beginnings of written history, a rude chemistry had been practiced by men. Iron was smelted, gold and silver were worked, salts were crystallized, glass was made, gunpowder and fireworks were compounded, drugs were prepared, cloth was dyed, fuel was burned, food was dressed, hundreds of chemically distinct substances were articles of trade,

and thousands of chemical facts were more or less definitely known. But all this chemical knowledge was empirical; each chemical fact stood by itself, having no apparent causal or associative relation to other chemical facts; each known chemical process was a distinct and separate art, apparently unconnected in principle to other chemical processes; all chemical industry was conducted by rule-of-thumb. Once in a while some more than usually perspicacious individual would find a principle that would embrace relationships within a certain group of chemical phenomena. Thus between them Boyle and Charles evolved the laws governing the behavior of gases; and by his discovery of the rôle of oxygen in combustion Lavoisier was enabled to show the similarity of such apparently dissimilar phenomena as the burning of wood, the rusting of iron, and the utilization of food in the bodies of animals. But all such knitting together of loose ends did not yet make a real chemical science; there was still lacking knowledge of the master principle that binds all chemical phenomena into one consistent system and gathers all the separate rules-of-thumb of chemical practice into a single homogeneous discipline. This master principle came to light when Dalton discovered the laws of definite and multiple combining proportions, and thus revealed the existence of atoms and molecules that retain their fixed characteristic of mass as they go through the vast series of transmutations and permutations with which chemists are now acquainted. In short, through Dalton's discovery, the chemist has

been enabled to reduce all his operations to a mathematical basis, to foresee the end from the beginning not only qualitatively but also quantitatively, and to test and control his progress at every step in the sure light of mathematical norms. All chemical phenomena are now subject to exact measurement, so chemistry has become an exact science.

This is the test of a real science: All the states of being or modes of interaction between the objects or phenomena that come into consideration conform to one or more master principles by which each individual phenomenon or object of the group may be dimensioned, and by which the permutations of these objects or phenomena may be predicted, controlled, and brought to a finish with quantitative exactitude.

Now, let us apply this criterion to that most ancient and human among the most important of the systems of knowledge by which men seek to maintain themselves in this difficult world. Is there a real science of plant growth and yield by which all agrobiologic phenomena may be dimensioned, permuted, controlled, and brought to a finish with quantitative exactitude?

Ten years ago the answer would have been almost unanimously, no. Those were still the days when the master principle that runs through all the quantitative phenomena of plant biology was still unperceived. The plant physiologists, the plant biochemists, the geneticists, the soil scientists, the agronomy professors, the farm management experts, had before them an immense body of recorded facts and experience which they might bring to bear on their labora-

tory and field experiments, and use in the instruction of the tens of thousands of students who flocked to the agricultural colleges for training as scientific agriculturists. But all this knowledge, as we have previously remarked, was essentially empirical and rule-of-thumb, a discipline with no definite starting point and no clearly visible end, an art with no certified yardsticks by which means could be dimensioned, in foreknowledge, to fit predetermined ends.

When we say that the agriculture of ten years ago was an art without certified yardsticks, the meaning is that it was without means or knowledge of how to find the true dimensions of the forces with which it was dealing. It was known, in general, that wrapped up in every seed there is an undefined power of life that could be evoked to an undefined extent by following a traditional, routinized practice. But there was nothing to show how great this power of life might be. Farmers, plant physiologists and all the other categories of plant biologists were well aware that plant growth and yield depend on various external circumstances and influences, such as water, light, warmth, air, and a variety of other agencies known collectively as soil factors; but beyond the teaching of experience that all these outer circumstances must be acting concurrently, little was known or suspected as to how these circumstances might be coördinated and proportioned, each to the other, so as to develop the maximum power of plant life. This inability to make a rational adjustment between the outer and the inner circumstances of plant life is

hardly to be wondered at, seeing that the maximum dimension of plant life itself was unknown. Farming was like a game played against an unseen opponent who had the advantage of loaded dice. To repeat, the farmer had no standards of magnitude for either what he hoped to obtain or for the means he employed to obtain it; he knew no definite unit of plant life and no corresponding units of the things on which the unit quantity of plant life depends. On his fields empiricism ruled supreme, and hardly less supremely on the beautifully laid out plats of the agronomy professors.

However, it is not to be supposed that the elements or raw materials for a scientific agriculture were entirely lacking. On the contrary, the experience accumulated through the ages since men first began to plant seeds has made certain principles so very evident that they have become ingrained in the perceptions of everybody concerned—farmers, agronomists, plant biologists, etc.—and are relied on without question and almost without thought. These principles are, in fact, precisely what we have named as the first requisites of an exact science of natural phenomena: a set of general principles or axioms by which all the phenomena involved may be assigned real dimensions and definite relationships. There are five of these axioms, and their authority is admitted to extend to every nook and cranny of the kingdom of Flora. The bankruptcy of pre-agrobiologic agriculture lay in the inability or omission of the scientific or lay plant biologists of the time to seek out the joint resultant

of these principles and evaluate therefrom the fundamental units of plant growth and yield.

What these self-evident, universal principles of agrobiolgy are, and how they have been knitted together to form the new science of agrobiologic dynamics, may now be discussed.

CONSTANCY OF GENOTYPES

The first general principle or axiom of agrobiolgy, inherited from time immemorial, is that in every duplication of a definite closed system or environment in which plants are grown, the genotypic characters of definite plant genotypes are constant. By "definite closed system" is meant a certain definite and reproducible combination of soil, moisture, light, temperature, etc., which is more or less congenial to the plants that may be growing therein, these conditions being maintained uniform during the growing period. By "definite plant genotype" is meant a distinct species or variety of plant—generally called "agrotype"—which is known to reproduce itself true to type when its seed is planted. By "genotypic characters" are meant those obvious features that are distinctive of the species or variety, and by which it may be recognized; it is these features that are infallibly reproduced when the environment in which the plants are grown is exactly reproduced. All this is merely the plant-biological equivalent of the adage: *like produces like*; when intelligent care is taken, each succeeding generation of plants is a true copy of the original.

A genotypic character of outstanding importance in agrotypes that are used as crop plants is yielding ability, or the quantity of vegetable material obtainable from a unit area of land.

The reader will understand that the constant yielding ability ascribed to definite plant types or agrotypes by the first principle of agrobiolgy relates not to absolute identity of weight or mass among all the individual plants, but is rather an attribute of the total mass of all the individuals on the unit area, which is usually the acre or the hectare. It is well known that when individuals of a species of either plants or animals are weighed and measured no two will be found exactly alike. But when the members of a large group of individuals are weighed the average weight, obtained by dividing the total weight by the total number of individuals, will be found in close agreement with the average weight of a similar group of the same kind of individuals. Specifically, the same number of bushels produced by a pure line strain of wheat on one acre of ground amid certain surroundings will be reproduced on any other acre of exactly similar character placed amid similar surroundings. In other words, the same set of causes always produces the same effect in farming, as elsewhere.

This law of the reproducibility and constancy of the characters of definite plant types, including yielding ability, is trusted by the farmers and the agronomy professors alike. It is explicitly or tacitly assumed in the practice of every experimenter in pure

or applied plant biology; and written into every bulletin issued from any agricultural experiment station is the definite implication that if the arrangements prescribed in the bulletin are exactly duplicated by farmers, the described results will be exactly reproduced. That is precisely what agricultural experiment stations are for.

Since we have set out to give the non-technical reader a firm grasp on the basic principles, the point may be illustrated by describing an experiment by two University of California professors, Davis and Hoagland. In this experiment a pure line strain of wheat was grown in a greenhouse where the plants were provided with uniform conditions of soil, temperature, light, moisture, etc., for a period of twenty-eight days; the plants were then harvested, weighed, and the height of the main stalk of each stool was measured. Then another crop of the same wheat was grown under exactly the same conditions for another period of exactly twenty-eight days, and so on for five succeeding crops. The average weights of the wheat plants, and the average heights of the main stalks in all five crops are graphed in Fig. 2. The results are identical within an average statistical error of less than one per cent, which from all practical standpoints in such matters is considered a satisfactory approach to constancy of reproduction.

The reader perhaps feels that it is a far cry from the rigidly controlled conditions of experimentation in a greenhouse, where expense is a secondary consideration and where the crops are produced by the

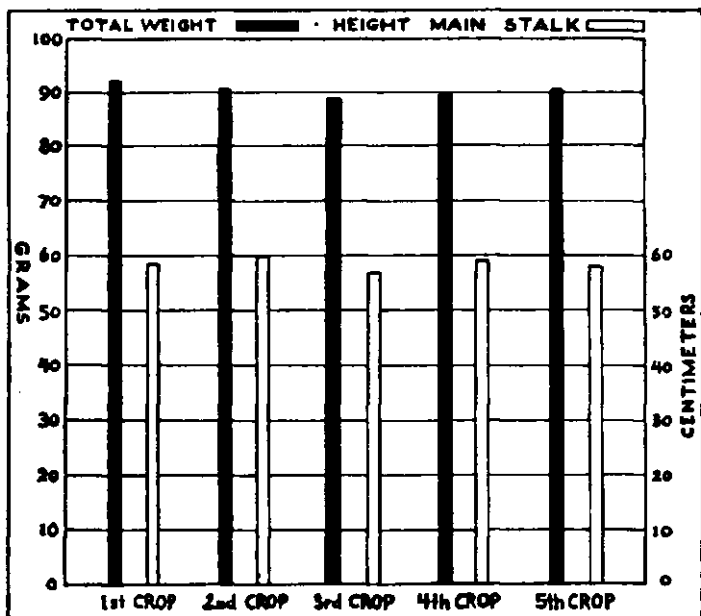


FIGURE 2. ILLUSTRATING CONSTANCY OF GENOTYPIC CHARACTERS IN A REPRODUCED CLOSED SYSTEM.

painstaking care of accomplished professors, to the broad acres, common labor, and exigent economics of a great plantation; we will take care of that in due course.

DEFINITE GROWTH POWERS

The second general principle or axiom of agrobi-ology is that every definite agrotype has a definite power for growth; that is, it possesses a definite and characteristic quantity of life that is measurable by the quantity of vegetable substance it will produce

on a unit area of land. This principle is, in effect, a particularization of the first principle, which states generally that the quantity of life (whatever that quantity may be) possessed by an agrotype is a constant; the second principle means that one agrotype may have a greater quantity of life than another, which coincides with the well known fact that one variety of crop plant is more or less valuable than another because it will yield more, or less, than the other on the same acre of ground. If two agrotypes differ in yield by a certain amount in one reproduction under stated circumstances, they will differ by the same amount in all reproductions under the same or similar circumstances.

If this sounds a bit complicated to the city dweller who has lived remote from agricultural matters, he may reflect that pure breeds of dogs tend to reach a certain uniform, characteristic size. The average weight of one hundred St. Bernards is a statistical constant, which is definitely and characteristically greater than the statistically constant average weight of one hundred toy spaniels. Such is the law of definite growth powers applied to plants.

The second principle of agrobiolgy also receives the implicit confidence of all practical and scientific plant biologists. Few operations by agricultural experimenters, anywhere, are more frequent than the comparative testing of different plant varieties in identical or comparable environments; in such tests the agrotype that demonstrates possession of the largest quantity of life is the one officially recommended

for reproduction in the same or similar environments. Such recommendation could not be made if the quantity of life resident in the agrotype were not constant.

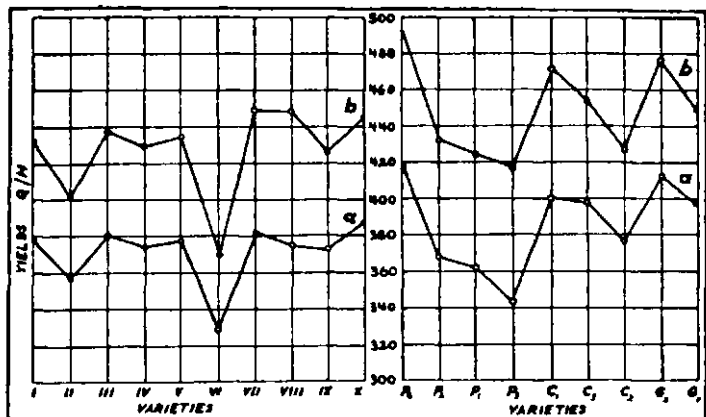
DEFINITE EFFECTS OF GROWTH FACTORS

The yield of vegetable substance from an acre of ground is the resultant of two distinct forces. On the one hand it depends on the quantity of life resident in the agrotype; and on the other it depends on the available quantity of the external factors of growth that are in action on that acre. In plain terms, if the soil is poor, the yield will be small; if the soil is better, the yield will be better; and if the soil is very rich the yield will be very good. There is a definite quantitative relation between soil richness and yield. This relation is constant for all duplications of the same system, so that if two acres of ground are equally rich they will give exactly the same yield of the same agrotype. Thus the constancy of growth-power or yielding ability of agrotypes stated in the second principle is matched by constancy of the growth-promoting power of the external factors that support growth, which is the substance of the third general principle of agrobiolgy; this principle is fundamentally nothing other than a phase of the universal principle of causality: a quantitatively definite cause always produces a corresponding quantitatively definite effect, in agriculture as elsewhere.

Like the two general principles of agrobiolgy already discussed, the law of definite effects of growth factors is firmly and justifiably believed in by all

farmers and all agronomy professors everywhere. It is the indispensable *a priori* basis on which the great fertilizer industry has been erected, and is always relied on by the agronomy professors when they make experiments for the purpose of advising farmers what kind and how much fertilizer to use. An agricultural experimenter, for instance, approaches the problem "to determine the fertilizer requirement of a soil." The soil as it lies before him represents a system that is, or is thought to be, deficient in plant food. A part of this system is left as it is, and on other parts different kinds and amounts of fertilizing materials are applied, thus giving the soil differing degrees of richness. The harvest will result in corresponding differences of yield; and the expert, relying on the constant relation of cause and effect, is in a position to advise the farmer as to how much produce he can expect from how much fertilizer on that kind of soil under the prevailing conditions.

As a composite illustration of the three general principles of agrobiolgy so far discussed the reader will please examine the diagrams of Figs. 3 and 4. These diagrams represent two different field trials intended to compare the relative quantities of life possessed by different sugar beet agrotypes when all were grown in two separate environments differing in a single particular. In one trial, executed under the supervision of Soucek (Fig. 3), ten sugar beet varieties were planted in a relatively dry soil (curve *a*), and again the same varieties were planted in a relatively moist soil (curve *b*); except for a constant dif-



FIGURES 3 AND 4. ILLUSTRATING CONSTANCY OF RELATIVE GROWTH POWERS OF AGROTYPES AND EFFECTS OF GROWTH FACTORS.

ference in moisture content of the soil all conditions were kept as nearly alike as possible. Examination of the two curves *a* and *b* will show, first, that all the ten agrotypes do not possess the same quantities of life as measured by their yields; and second, that if an agrotype gives a relatively low yield in the drier soil it gives a relatively low yield in the wetter soil; and conversely, if it gives a relatively high yield in the drier soil it gives a relatively high yield in the wetter soil. Further, the constant difference in moisture between the two soils affects the yield of all the agrotypes in the same relative proportion: multiplying the yield of any of the ten agrotypes in the drier field by 1.15 gives its yield in the wetter soil (within satisfactory limits of error for that kind of work). The same qualitative and quantitative relations are

demonstrated by the experiment graphed in Fig. 4, which was executed by Soucek in collaboration with Koslecki; here nine beet agrotypes of different origins were planted in Bohemia and in Poland under identical conditions except for a constant moisture differential. In this diagram curve *a* represents the yield in the drier, and curve *b* the yield in the wetter soil.

In these experiments the reader is expected to see a verification of the second principle of agrobiology, which is that every agrotype has its fixed position on a scale of relative growth power; and a verification of the third general principle, which is that a definite variation in the amount of a growth factor produces a corresponding definite variation in the yield of agrotypes, this differential effect being in constant proportion to the inherent growth power of the agrotypes.

The upshot of it all is that plant life, in any given closed system, can be dealt with as a constant, measurable quantity, and that growth factors can be dealt with as forces having definite and measurable magnitudes. It is of such stuff—constants—that mathematical sciences of natural phenomena are made.

However, to arrive at a mathematical science of agrobiologic dynamics it is not sufficient to know that the quantity of life resident in an agrotype is constant, and that in identical closed systems growth factors exert constant effects. No real science of plant growth and yield is possible without something that will show the numerical relation between quantity of growth factor on the one hand and quantity of

yield on the other hand; science requires that the relation between cause and effect be capable of accurate measurement in standardized units. The three general principles or axioms of agrobiolgy given above do not of themselves contain an indication of what these units are, or how they might be evaluated, and a fourth general principle must be sought that will bring these units to light.

DIMINISHING INCREMENTS

This necessary fourth universal principle or axiom of agrobiolgy is found in what was first stated by the English economist John Mill (about 1823) as the law of diminishing returns. This law occupies a prominent place in every high school and college course in economics. As applied to agriculture the meaning is that continued increases in effort and expense bestowed on the soil eventually fail to return a proportionate increase in yield. In the terminology of the scientific agrobiologist this law is stated thus:

“As the amounts of the essential factors of plant growth in an initially barren closed system are progressively increased by equal increments, the yield of plants grown in the system is also increased but at a diminishing rate, and tends to approach a limit.”

Like the other axiomatic principles of agrobiolgy, this principle, which for agrobiologic purposes is referred to as the law of diminishing increments of yield, rests on the truth of universal experience in plant culture. Recorded observation in all ages, in all climates, and with all agrotypes agrees that the yield

of no familiar species of plant can be increased beyond a certain limit by any known play of natural forces, or by any art or device of men. In other words, no known agrotype can display an unlimited quantity of life on a unit area of land in one growth cycle. Further, all trustworthy experience agrees that each progressive increase in the quantity of any external factor of plant growth acting in the unit area is attended by a decrease in the rate of increase in the yield of the plants; the increase produced by the n th unit of a growth factor is proportionally greater than the increase produced by the $(n + 1)$ unit, until finally, further increase of the growth factor fails to evoke further perceptible increase of yield.

This principle completes the *a priori* basis of the science of agrobiologic dynamics. The rest is accomplished by ordinary mathematical processes of no great complexity, by which the principles are placed in proper relation to each other so as to arrive at their joint resultant. That is what pre-agrobiologic agriculture failed to do, not because it was hard, but simply because it was not thought of before.

The underlying principles which we have been discussing at some length furnish three unmistakable starting points: the constancy of the growth power of a definite agrotype; the constancy of the action of a definite quantity of a growth factor in a definite closed system; and a continuous decrease of the rate of increase of yield with continued increase of the amount of growth factor in action.

The process of mathematical thought in effecting

a synthesis of these fundamentals is pictured in Fig. 5. The horizontal axis in this diagram shows units of a growth factor, called x , which is increased by equal increments in a series of systems which are otherwise suitable and adequate for normal plant growth. Since

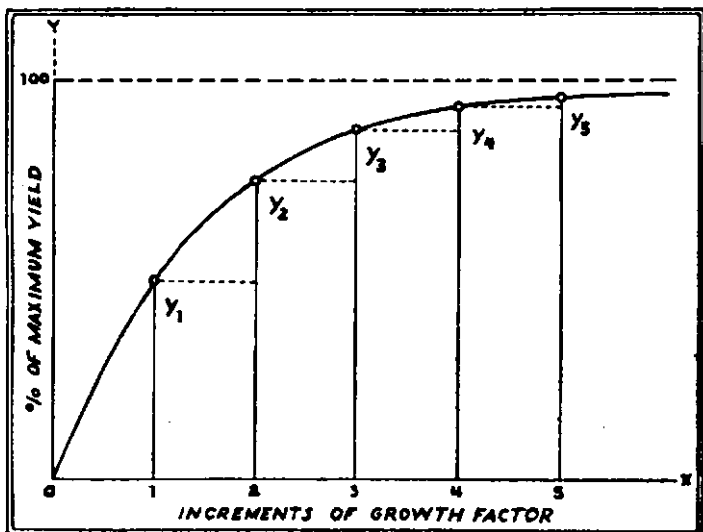


FIGURE 5. TYPICAL YIELD CURVE OF AN AGROTYPE UNDER THE ACTION OF INCREASING AMOUNTS OF A GROWTH FACTOR IN AN OTHERWISE UNIFORM ENVIRONMENT.

there is not necessarily any limit to the number of units of the growth factor that may be added to the soil, the horizontal axis may be indefinitely prolonged. The yields, y , obtained from the systems by progressive enlargements of the quantity of x in action, are marked on the vertical axis. This axis is not indefinitely prolonged, because there ultimately

comes a limit to the yield of any agrotype that may be grown on a unit area of land. The numerical value of this maximum or limit yield is not as yet determinable on *a priori* grounds for any agrotype; but whatever it may be, it can always be represented as 100 per cent of what it is possible to obtain under the best possible circumstances. The y axis may therefore be divided into 100 equal parts.

Let us now suppose that at first the system is completely barren; that is, it contains no x , and without x no plant will grow, no matter how favorable the circumstances otherwise. The yield under this circumstance will be zero, and this condition will be represented by the point of intersection of the two axes. When one unit of x is added there will be produced a yield y_1 ; two units of x will produce a yield y_2 . But this yield y_2 , produced by two units of x , is not twice as great as the yield y_1 , produced by one unit of x , because as the quantity of a growth factor in action is increased the rate of increase of yield decreases; and for the same reason the yield y_3 , produced by three units of x , will not be three times as great as the yield y_1 nor $1\frac{1}{2}$ times as great as y_2 ; such is the teaching of universal experience. And so on; as x is increased the increment of yield becomes less and less and tends to become vanishingly small; the curve bends over as it rises and appears to merge imperceptibly with the 100 per cent yield line. A mathematician would say that a curve developed in this manner is an asymptote.

THE UNIVERSAL YIELD EQUATION

The yield curve shown in Fig. 5, which represents the action of definite quantities of a growth factor on a definite plant type in a series of definite, homologous closed systems, is infallibly reproducible because the value of any point on the curve represents a constant ratio between two definite and constant forces. Like any other definite curve showing the relation between two variables x and y , this curve can be expressed in a mathematical equation. In this case, since the value of y under the influence of increasing amounts of x tends asymptotically to approach 100, the expression connecting x and y must take the form:

$$dy/dx = f(100).c,$$

in which c is a factor of proportionality showing how y approaches 100 per cent.

So, when finally boiled down together and crystallized, the four universal principles yield a statement that the quantity of substance produced by an agrotypic under the influence of increasing quantities of a growth factor is an asymptotic function of 100. From the vast store of records, experience and investigations accumulated by experiment stations and well-managed plantations in all parts of the globe, it is easy to identify this asymptotic function as

$$(100 - y)$$

and to fix the value of c at 0.301, so that, by integration, the end-result of all this ratiocination and synthesis finally emerges as

$$\log(100 - y) = 2.0 - 0.301x.*$$

This, then, is what the agrobiologist really has—an equation. But how does this one equation, which is simple enough to be managed by any bright high school sophomore, change the face of man's greatest industry and substitute precision and foreknowledge for empiricism in the most empirical of all arts? How will it rescue the old, traditional agronomy from its bankruptcy of failure to meet the needs of isolated groups whose necessity for agricultural products bulks larger than the present capacity of their soils? Will the agrobiologist essay to spear the war-devil—on an equation?

The equipment which the agrobiologist is now seen to bring to the proposed foray against the formidable population problem might indeed appear, at first sight, to be scant and inconsequential. But what is contained in this equation may well be inferred from what we have seen to go into its synthesis. It has sprung from universals, therefore it is itself universal.

* The reader who is "mathematics shy" may well make a special effort to cultivate the acquaintance of this equation: it is one among the most beneficent aggregations of mathematical symbols ever put together for the guidance of humanity in this vale of hardship and privation. If he is minded to pursue the matter the reader will find more details in the Appendix.

It originates out of self-evident truths that encompass every species of plant and every factor of plant growth in which men have been or now are interested; therefore it encompasses the quantitative relations between *all plants and all growth factors*. It is the universal, certified yardstick by which all the living and inanimate forces that enter into plant culture may be dimensioned, permuted, controlled, and brought to a finish with quantitative exactitude. The powers of life that reside in the myriad forms of vegetation are reduced to a common denominator, and all the millions of variations of soil in which plants grow anywhere on the earth are brought under a single rule of quantity. Whatever the species, or whatever the longitude, latitude or climate in which they may be grown—whether wheat in Australia, rubber in Java, tea bushes in India, cotton and maize in Egypt, oats in Germany, sugar beets in Sweden, pine tree seedlings in the New York highlands, potatoes in the State of Washington, pineapples, Sudan grass or sugar cane in the Hawaiian Islands—all agrotypes follow the norms of growth and yield laid down in this one equation.

The universal yield equation states that for the production of a certain required yield y , a corresponding definite quantity of x must be put in action. Strange as it may seem, in spite of its vast organization for experimentation and research, pre-agrobiologic agriculture had attained practically no conception of this definite quantitative requirement.

THE FIFTH UNIVERSAL PRINCIPLE

There may still be readers, including even some of the egregious individuals who insist that there is a "soil science," to whom the reduction of such vast complexities to such astounding simplicity must appear as the imagining of a diseased intellect. Indeed, are there not great differences in plant types, and vast differences in "soil types"? Consider the perennial sugar cane and the lordly *Hevea*, which will flourish only in a hot and wet climate—what have they in common with cold-defying, evanescent annuals like oats and the potato? And soils—is there anything more variable than soil, which ranges through every possible gradation of mineral composition and state of physical aggregation? The United States Bureau of Soils has named and mapped thousands of "soil types," and, at that, has not yet surveyed half the country. And even within these named soil types there is infinite variation; it is a fact that no acre of soil is exactly like any other acre of soil on the face of the earth.

But through all this apparent diversity and complexity there runs a fifth universal principle that is admitted on all hands to apply to all known forms of plant life wherever or however grown. This principle is that all agrotypes of whatever description are nourished by the same small group of what are called plant nutrients or, more generally, growth factors. For instance, every known agrotype, whether peaches or peanuts, apples or artichokes, needs water. Again,

every agrotype of whatever description must have phosphoric acid, or it will not grow at all; and if the agrotype is well supplied with both water and phosphoric acid but is deprived of nitrogen, it still will not grow. There are about a dozen of these indispensables, and they must all act together. The question of soil is wholly secondary. Any soil in any country will do, provided only that it is sufficiently loose and non-poisonous; in so far as there is such a discipline as soil science its *bona fide* content relates to the loosening and sanitation of the inert material in which growing plants must have their footing.

It is this fifth principle—the law of the universality of growth factors—which states that all plant growth depends on the joint action of a limited ensemble of agencies, that introduces simplicity into the seemingly interminable maze of circumstances that encompasses the life of plants. The problem of managing y would be hopeless if x had to represent as many growth factors as there are varieties of soil and climate. But the number of different x 's that come into consideration is limited to hardly more than a dozen; and as every agronomist and every plant physiologist understands, at least half of these are everywhere furnished by Nature in sufficient quantity. The problem of managing the infinitely varied y 's is thus reduced to the management of a few different x 's, which can be introduced one after the other into the universal yield equation, and the whole design of the crop of any agrotype is easily completed before the seed is planted.

Thus the agrobiologist has a definite measure for

all the necessary few external circumstances that must be assembled in order to produce a required yield of any of the agrotypes on which men anywhere depend for sustenance; means can now be exactly matched, in foreknowledge, to pre-determined ends.

Naturally, when it comes to a question of raising the productivity of the soil of some hard-pressed group that is living in a commercial mono-vacuum, the object will be to make what is "required" coincide as nearly as may be with what is "possible." But here we meet the condition that what is agrobiologically possible is strictly limited by the law of diminishing increments. No known agrotype can yield an unlimited amount of vegetable produce. So beyond a certain point no enlargement of x will enlarge y . It is therefore essential to find out what is the maximum attainable y in order that the proper adjustment of x may be made.

Here is where agrobiologic science has made its second great contribution to man's prolonged endeavor to gain mastery over Nature. The uttermost limit to which y may be pushed has been determined for the most important agrotypes, and is determinable for any. This was the great mystery of the pre-agrobiologic agronomist and plant physiologists, who had no conception of plant life as a force having fixed and measurable dimensions, and from whom the real magnitude of this force was still hidden. The author has previously had occasion to outline the *modus operandi* of this determination in a popu-

lar book,* and the subject has now been well covered in the proceedings of learned societies and in technical books and articles in all the principal languages; but to give a grasp of the matter to the reader who may not have access to these sources the procedure may be briefly reviewed.

It has already been remarked that the universal yield equation

$$\log(100 - y) = 2.0 - 0.301.x$$

is within the mathematical competence of any bright high school sophomore. In this equation the numeral 100 represents the maximum or 100 per cent yield of any agrotpe when all conditions in a closed system are optimum and all necessary growth factors are present and acting in their maximum effective amounts. If all but one factor are present there will not be any yield until some of the missing factor is added, and the yield will increase in accordance with the law of diminishing increments until the maximum effective quantity of this factor is also present. To ascertain how successive additions of the deficient x reacts on y , we have only to insert in the equation a succession of increasing numerals as 0.25, 0.5, 1, 2, 3, 4, etc., representing fractions or multiples of one unit of x ; the corresponding percentages of the maximum yield are obtained directly, and may be gathered into Table III.

* *Reshaping Agriculture* (Norton, New York).

TABLE III.—SHOWING RELATION BETWEEN UNITS OF A GROWTH FACTOR AND PERCENTAGES OF MAXIMUM YIELDS

units of growth factor *	percentage of maximum yield
0.25	16.3
0.5	29.2
1	50
2	75
3	87.5
4	93.6
5	96.8
6	98.5
7	99.2
8	99.6

It is unnecessary to extend Table III any farther, because the yield in any case cannot possibly exceed 100 per cent. The eighth unit has brought it up to 99.6 per cent and the ninth unit could add only a small fraction of 1 per cent; for all practical and most scientific purposes of plant biology an approximation within less than one half of one per cent is a sufficient approach to complete accuracy. It can thus be assumed that if a closed system be prepared containing eight or more units of each of the dozen known essential factors of plant growth, any agrototype planted in such a system will grow and yield to the very limit of its inherent ability. In this simple manner is the full quantity of life resident in any useful plant measured; and from what has gone before it is superfluous to

* These units are Baule units; see Appendix.

remark that when the same system is duplicated anywhere the same maximum quantity of plant life will again be displayed. It should by now be sufficiently clear that both the inner and the outer factors involved in the production of agricultural raw materials are constants and have definite and measurable magnitudes.

It is possession of this truth, plus knowledge that *the maximum measured yielding ability of common agrotypes is immensely greater than the old agronomy ever suspected* (see Table VI, p. 170), that warrants an agrobiologist in thrusting himself into the question of pressure of population on the soil. Agrobiology is a new science, which has not yet had time to spread itself sufficiently among those most concerned. It bears the keys to fresh stores of world-wide abundance, available not merely in fortunate sections, but wherever the new concepts are put to work. It is already a light that is not hidden, and only needs to be further divulged, with the special object of bringing relief to those sore spots in the world body-politic, where national want, privation and envy are brooding new calamities.

Is a marooned nation pinched by a supposedly inadequate soil? Before the military chiefs are consulted as to the practicability of enlarging the national resources by rapine under the cloak of some convenient pretext, let the national soil itself be put under agrobiologic scrutiny.

What the reader is expected to gather from this chapter is that we now know exactly what must be

done to confer maximum fertility on the soil—any soil, and that the components of maximum fertility are the same for any and all soils. A poison-free, moist soil that contains more than eight units of each of the indispensables will produce the maximum yield of any vegetable that grows, whether pansies or bananas. Therefore, since we know how to bring any soil to the limit of fertility, we know how to obtain the ultimate yield of any agrotype, and we further know that if we are in command of the necessary materials and have previously measured the quantities of life resident in our agrotypes, we can calculate with sufficient accuracy, beforehand, what the result will be. For the purpose of the discussion which is to follow it is not necessary to explain to the general reader how the units of soil fertility are assigned definite values, or how units of soil fertility are numerically related to units of crop yield, but if he so wishes he can satisfy his curiosity by studying the Appendix.

Chapter V

DELIMITING THE POPULATION PROBLEM

SO LONG as the pre-agrobiologic agronomists were floundering in their seas of empiricism, with no compass in hand and no landmarks in sight, with no conception of the maximum productivity of land and hardly any criteria of general quantitative diagnostic or prognostic value, just so long were the sociologists and the practical politico-economists left without means of delimiting the population problem.

In so far as this problem involves providing a population group with the necessities of life it centers about two principal components: the number of persons to be provided for, and the capacity of the source of supply. It is easy enough to count the population; and if the utmost capacity of the source of supply has been ascertained the problem, though it may not be thereby disposed of, is at least fully delimited. Whether a satisfactory practical solution is found will depend on whether the source of supply is or can be so dimensioned that it will be able to meet all demands that may be made upon it.

As matters now stand the student of the population problem is quite clear on two points: that in some

regions the source of supply is perilously small, and that the old agronomy is incompetent to furnish specifications for enlarging it. In this conjuncture the new agrobiology appears, bringing a more penetrating insight.

It will not do to regard the problem as simply a question of ratio or relation between the number of consumers and the area of arable land from which supplies might be drawn. On the one hand, the per capita consumption has to be taken into account. The population may live on a low, a medium, or a high level of comfort—the higher the more satisfactory both to themselves and their neighbors because, other things being equal, a well-fed nation may be presumed to be more contented with its place in the sun than one that is poverty-stricken.

On the other hand, land area is a poor—we may say non-informative—measure of potentialities for agricultural production. Strange as it may sound at first, land or soil does not produce food, at least not in any more real sense than a pot produces soup; an acre of land and a soup pot are at best merely theaters on or in which certain interactions occur between factors that are entities of themselves. The physical dimensions of the pot or the acre do not set the true limit to the capacities of either, but rather the time-concentration ratio at which these containers are put through the cycle of operations that go on within them; the equivalent industrial and commercial expressions are "through-put" and "turn over."

For a measure of the potentialities of food pro-

duction we must therefore have measurements of the entities that meet on the unit area of land. We must above all ascertain what is the limit of through-put of these entities in the unit of time; this will show us what is the maximum possible rate of production, taking for the unit of time either the calendar year or the period occupied by the growth cycles of whatever agrotypes may be under consideration. By maximum productivity of land is to be understood the utmost that may be got out of it when handled, not by the common run of untaught and unguided rustics, but by industrious cultivators under the direction of skilled agrobiologists who have at their command all necessary materials and facilities. Under this condition all will be produced that can be expected. If this limit quantity of produce is now divided by the per capita allowance, the maximum number of persons who can be sustained on a fixed area at a given level of comfort becomes known. Having thus been dressed in figures, the population problem can be deposited on the doorsteps of the politico-economists and the initiators of social action, with the hope that they will handle it wisely in full comprehension of the authentic agrobiologic information furnished to them.

Since the most worthwhile social and political action against situations arising from pressure of population on the soil may well be based on the maximum productivity of land as the fundamental reference point, the contents of this base should be thoroughly understood. The author has already de-

finest maximum productivity of land in a book written for laymen in another connection,* but as the subject is now to be handled specifically in connection with the population problem it may be briefly reviewed.

In a preceding chapter it was mentioned that the agrobiologist has a method for measuring the present full quantity of life that resides in any agrotype. This method consists in creating an environment in which eight or more units of every one of the dozen essentials of plant life are present and acting. A soil thus equipped is what the agrobiologist calls a *perfectible soil*, meaning a soil that has been made so rich that for any practical or scientific purpose of plant culture it will be useless to make it any richer. Under these circumstances no species of plant whatever can fail to grow to the utmost limit of its vital power.

When this is done with several different kinds of plants it is observed that some show greater vital powers than others, as measured by the respective weights of dry vegetable substance produced. For instance, a certain corn-agrotype may be found to have a quantity of life represented by 100 bushels of grain, whereas a second corn-agrotype is found to rate 150 bushels, a third 200 bushels, etc. Obviously, the produce of neither the first nor the second corn-agrotypes represents the limit of corn production per unit of area; the third, with its 200 bushels, *may* represent the maximum, but we cannot be sure un-

* *Loc. cit.*

less we have something to indicate what the absolute limit to corn production is. However, a method for determining the absolute as distinguished from the apparent limit to the vital power of any agrotype has now been provided by agrobiologic science, and thus the absolute maximum productivity of land as regards any kind of crop is open to measurement. The scientific principles involved in these measurements are explained in the Appendix, but for the benefit of the reader who does not care to tackle the inevitable mathematics it may be stated here that it has all been reduced to the following simple rule: Divide 318 by the normal percentage nitrogen content of whatever agrotype is being considered; the quotient is the theoretical absolute maximum number of pounds of dry vegetable substance which that agrotype can yield on one acre of ground in one crop cycle.

In the development of his science the agrobiologist has found it convenient to coin a special terminology, including certain new words with which those interested in the fundamentals of the population problem will need to become familiar. A *perfertile soil* has already been defined as a soil that contains eight or more units of all essential growth factors. Any agrotype grown in such a soil must of necessity give its *ultimate yield*. But the ultimate yields of corn agrotypes, for instance, differ among themselves in accordance with the respective maximum quantities of life resident in these agrotypes as determined by the method previously described; some actually give

the yields called for by the formula $318/n$, others do not (in this formula n is the nitrogen percentage). The yield of a corn-agrotype that does correspond to this formula is called a *perultimate* yield, signifying that it is the *ne plus ultra* of production which corn-agrotypes may attain but not surpass. An agrotype that gives the perultimate yield is called a *perultra agrotype*, to signify that it has arrived (by natural selection or by breeding) at the Ultima Thule of vital vigor. Those agrotypes whose ultimate yields in a perfertile soil fall short of the perultimate required by the formula are described as *subultra agrotypes*, indicating that there is still a margin within which the geneticists and the plant breeders, using the processes of induced evolution with which these specialists are familiar, may enlarge the vital powers of these lagging or deficient types.

These definitions point directly at the two prime agencies which the agrobiologist must use for attaining the maximum productivity of land: a perfertile soil, and perultra agrotypes to grow in it.

The sociologists, the politico-economists, the pacifists, and all persons who sincerely hope for the day when the nations may contentedly live at home, will therefore not fail to note that whenever the soils of a nation are made perfertile, and when only perultra agrotypes are grown in the fields (excluding all inferior subultra types), that nation will be producing all the agricultural raw materials which it can ever hope to obtain from its home acres. By the same token, no nation will have reached the limit of its

capacity to live in peace and plenty at home until it has brought all its farm land to the limit of fertility, and has required its cultivators to grow only those types of plants that have demonstrated possession of the maximum quantities of life pertaining to their respective kinds. No marooned group can justify a policy of aggression against other groups under a plea of pressure of population on its soil while it is still remiss in drawing from its own possessions all that agrobiology can bestow in the way of a comfortable existence. *Per contra*, it will be in a position to make out a good case for a larger share in the world's resources if it has demonstrated that the limit to the capacity of its fields has been reached, and that for the future it must either undergo social strangulation or resort to other means which need not be mentioned.

This should afford a pragmatic pacifism a double base for its efforts to promote peace: on the one hand an appeal to potential aggressors to avail themselves of internal self-help, and on the other hand a hint to possible victims of aggression to recognize the genuineness of a dangerous situation and to forestall trouble by neighborly action that will prove far less costly in the end than to allow matters to drift into a cataclysm. This suggestion may be presuming much on the sapience and good will of nations that are in possession of more than they need, but the argument need not be pitched in the tune of pure altruism. If richly endowed nations must consider everything from the standpoint of purely selfish national interest, let

them be brought to consider what form of national selfishness is most compatible with their own national well being and safety. International pacifism will gain in respect when it is able to demonstrate a price for peace that can and should be paid.

THE PRIMARY LIMIT

However that may be, our present business is to explore the land-population ratio, remembering that when we speak of land area as a factor in the population problem we really mean the time-concentration value of the factors whose interaction occurs on a unit area. Moreover, in computing the number of persons who can be maintained on a fixed area, it will be useful to follow out the suggestion previously made and disregard at first all questions of standards of living, taking as the basic unit of calculation that minimum quantity of vegetable substance that will just suffice to maintain one average person in reasonable health and activity for one year; this will define the unit ration for the lowest admissible level of comfort. The value of this unit ration being known, and the maximum number of such units that can be obtained from one acre of ground having been ascertained by the agrobiologists, a simple division will give the number of persons that will just saturate one acre of arable land with population at the minimum standard of living. This basic unit having been set up, saturation limits can be computed for cases where the individual is allowed $1\frac{1}{2}$, 2, 3, units. The standard of living for the group being thus

postulated, and the size of the group being known, a simple calculation will show how many acres of the national domain must be cultivated according to the best agrobiologic practice in order to meet the assumed requirements. Such a calculation will reveal whether the national resources in land and other natural materials required by the agrobiologists are adequate to the proposition.

The first operation in this study will be to define the unit ration, which we will fix at 2,500 food calories per day, with the specification that this ration shall include 50 grams (1.763 ounces) of protein, the entire ration consisting exclusively of vegetable products. This undoubtedly represents a low level of comfort, but it is still enough to enable people to exist and do a reasonable amount of work, and is intended mainly as the basis of reckoning.

We will next consider the protein component of the basic ration. This substance, which is really of a composite nature, is fabricated by plants out of the nitrogen which they take from the soil. The quantity of protein contained in a food product is ascertained by analyzing the product and multiplying the amount of nitrogen found in it by an appropriate factor, usually 6.25. Now protein is what Huxley has aptly termed the physical basis of life; in the form of protoplasm it is the exclusive carrier of all vital functions, and of protein it has been said that it "furnishes the intimate corporeal substance of the bios." There can be no substitute for protein in the diet of animals,

including man. A well-rounded diet may consist of protein, carbohydrates and fats (not overlooking vitamins), but the functions of carbohydrates and fats are practically limited to the furnishing of heat units; protein is indubitably the one food element that is indispensable for the maintenance of animal life.

This being the case, and plant life being the ultimate source of all protein consumed by humans, it is evident that protein production per unit of land area is in itself a limiting factor on density of population. Since the individual is not to be allowed more than 50 grams of protein per day, the "saturation number" of an acre of ground in respect of population is determined if we know the limit to the amount of protein that can be produced on one acre. This we can readily ascertain. From agrobiologic data (see Appendix) we learn that the utmost quantity of nitrogen that can be resorbed by a perultra agrotype growing on an acre of a perfertile soil is 318 pounds. Multiplying this figure by the factor 6.25 gives, in round figures, 2,080 pounds of protein. Remembering that the daily protein ration is 50 grams, and making the necessary conversions and calculations, it results that one acre of ground can supply, at the maximum, the minimum protein needs of 51 persons for one calendar year. As there are 640 acres in a square mile, it follows that it requires 32,640 average persons to just saturate one square mile of arable land with a population living at the lowest admissible level of

protein intake. For comparison, the average density of population in the five boroughs of the city of Greater New York is hardly 25,000 per square mile.

QUALIFYING THE PRIMARY LIMIT

However, this population density limit of 32,640 per square mile is subject to various qualifications, subtractions, and even to additions, depending on circumstances and contingencies, and also on whether certain practicable expedients are resorted to. We shall first consider the qualifications and subtractions that have to be envisaged, and later on the possible additions.

The first qualification is that none of the 2,080 pounds of protein be lost on the way from field to stomach. This means that the protein must be consumed as vegetable protein, none of it being diverted to the feeding of domestic animals. A population of 32,640 persons subsisting on the annual protein yield from one square mile of arable land must be strictly vegetarian and painfully economical in the use of food.

The second qualification is that a perultimate yield of protein must be obtained every year with absolute regularity. Since in no case can the direct yield of protein from one acre of land exceed 2,080 pounds, and since by hypothesis the density of the population is to be exactly adjusted to this amount of protein, even a temporary decrease in the supply may be supposed to have fatal results for some of the population. To cover this situation the agrobiologists must make

their calculations and carry out their work with clock-like precision.

This at once raises the question as to whether agrobiologists can achieve clock-like precision on the open fields.

To those who have some acquaintance with ordinary agriculture as carried out by ordinary farmers with such assistance as could be given them by the old agronomic science, this will seem an impossible requirement. The average farmer, for instance the average American farmer, is notoriously beset by untold difficulties which an old-line agronomy professor could take hours to describe. Listen to the reaction of a director of the New Jersey agricultural experiment station when he first heard of agrobiology:

"There are too many factors which influence the growing of crops in the field to justify our attempting exact forecasts. Every student of soils and plants knows that we must reckon with the reciprocal effects of plants. Plants growing in associations behave differently than the same plants growing in pure cultures [stands]. It is well known that crop rotations are significant for various reasons, and that the influence of plants on those that follow is not to be ignored from the economic point of view.

"The symbiotic and non-symbiotic fixations of nitrogen are not definite quantities even when soil and climatic conditions are fairly definite. We know that there is great variation in the quantity and quality of the soil microflora including bacteria, fungi, protozoa, and nematodes. Soil infesting insects are a crop production factor of no mean significance. The same may be said

safely of plant diseases, of economic insects and of parasites.

"The student of soil fertility must make due allowance for the quality and quantity of soil organic matter. He must make allowances for soil texture and soil colloids in so far as these affect the movement of plant nutrients, of soil gases and of soil moisture. Much may be said about the root systems of plants and their distribution, about the water requirements of plants, drought resistance, and the relative efficiency of different varieties of plants in the assimilation of nutrients derived from soil and atmospheric sources. Soil reaction, the significance of elements like manganese, copper, boron or iodine, the significance of chlorosis, variations in the feeding habits of crops in different seasons and numerous other observed facts indicate that the production of crops cannot be measured in as definite terms as the purely theoretical considerations would indicate."

Drought; too much rain; irregular rain; bugs in, on and above the soil; rust, blight and other plant diseases; microbiological complexes, soil complexes, plant-physiological complexes, not omitting mental complexes; all these and more beside take their toll of the ordinary farmer's crops. The picture need not be enlarged; the existing conditions speak for themselves. Bumper crops alternate with failures, and the ordinary farmer hardly knows how much he will reap until he is ready to go forth to the harvest. Still,

"... to take arms against a sea of troubles,
and by opposing end them"

is not nearly as difficult as might be supposed, once the arms that may be used are known. And they are known. The conduct of agricultural operations is something to be approached in the spirit of Grant, who ordered one of his officers to "stop thinking about what Lee is going to do, and think about what we are going to do." What the agrobiologist does is to provide those positive factors which he knows must be present and acting; when this is done the negative factors disappear of themselves. The positive factors that must be present and acting are few and easily enumerated, and it is not impossible to assemble them on the fields of any nation where a considerable population has already established a settled agriculture. We have already indicated these essentials: a loosened, non-poisonous soil that has been made perfertile by the addition of a sufficient number of units of each of the necessary plant foods; a sufficient supply of moisture; and cultivation effective enough to suppress weeds. Surely this is no complicated specification, and where fulfilled it is not more certain that the sun will rise than that any stabilized agrotype will reproduce itself faithfully every time it is planted in such an environment.

What if symbiotic and non-symbiotic fixations of nitrogen are not definite quantities? Totally immaterial; the agrobiologist in any case counts his units of nitrogen beforehand and puts no dependence on haphazard natural processes. It is precisely the distinction of creative agrobiolgy, as it is of creative chemistry or creative engineering, that nothing is left

to chance which can be made secure by prudence. What of soil texture, soil colloids, soil reaction? They are all taken care of when the soil is loosened and made non-poisonous. What of manganese, copper, boron, iodine? What, indeed; are they not already given their due place in the list of the necessary components of a healthy perfertile soil? Chlorosis? A dime's worth of iron per acre will banish it. Soil bacteria, soil fungi, protozoa? They are absolutely negligible in any aerated, non-poisonous perfertile soil. Nematodes? One gets the impression that the New Brunswick agronomists are at a loss what to do about nematodes. What of crop rotations and the reciprocal effects of plants? Any differentials arising from such sources are abolished, without trace, when the soil is made perfertile by purposed attention to its known deficiencies, and the modern agrobiologist understands perfectly how to identify and measure these deficiencies. What of root systems, distribution of roots, water requirements of plants, the relative efficiencies of different varieties of plants, the feeding habits of plants? These are genotypic characters that may be recorded once for all time; the agrobiologist depends on no agrotypes whose natures, whose life powers, whose special requirements, if any, he has not accurately measured beforehand, which means that when a skilled agrobiologist sets out to produce a crop he knows exactly what he has to deal with and what he needs to do it with.

The reader will perhaps be better satisfied if he sees a concrete example of this "farming by blueprint."

Let us take a look at skilled agrobiologists in action.

On the island of Java is a sugar-cane plantation, called Ngandjoek, that covers an area of 4,200 acres which are operated subject to regulations imposed by the agricultural authorities in the interest of the natives. These regulations require that the land be used alternately by the European lessees for growing their sugar cane and by the natives for growing their food crops. The practical arrangement is that when the cane on half the terrain (2,100 acres) has been cleared away the native cultivators take possession and the next cane crop is planted on the other 2,100 acres, from which the natives have previously harvested two crops of miscellaneous agrotypes: maize, rice, beans, vegetables, etc. We thus find a rich assortment of those complexities that have been the despair of the old-line agronomists: radical differences in the previous cultural and rotational histories of the fields, superposed on radical differences in the original characters of the soils themselves; radical differences in microbiological complexes and in the organic matter content of the soils; a wet and a dry season, both irregular and uncertain; a hot climate peculiarly favorable to plant diseases and insect pests. What will the agrobiologists do with such a disharmonious system?

At the inception of each new cane crop the situation is "blueprinted." Each distinct soil of each field is analyzed or tested by methods that are expeditious, accurate and inexpensive. The soil's content of plant food and plant poisons thus becomes known; the

poisons are attended to, and the deficiencies of plant food on each distinct area are made good by measured applications of fertilizers. Rotational differentials are thus wiped out, and agrobiologic uniformity is established. The entire plantation is then plowed up, and the various soils are reduced to a physical state and texture that are suitable for the sugar-cane agrotype that is to be planted. This agrotype, the name of which is POJ 2878, was bred about ten years ago and is known to be the best of its kind, possessing the largest quantity of life of any that have been tried out on the island in a hundred years. Furthermore, the power of life that resides in this agrotype also has been thoroughly "blueprinted." It is used on all the other 170 sugar-cane plantations of Java, and between them the planters and their experiment station have subjected it to more than 10,000 separate scientific investigations, so that there seems to be nothing of importance about its ecology, pathology, physiology, agrobiology, root system, water requirements or feeding habits that has not been made a printed record. With this complete knowledge of all the animate and inanimate factors involved it only remains to plant and cultivate in a predetermined routine, and to concert measures beforehand against diseases and insects. These pests also have been "blueprinted," and while neither can be wholly suppressed they are reduced to a state of balance or equilibrium above which they cannot rise to do material damage.

We have now to examine the result of all this blue-printing of the animate and inanimate factors that

enter into crop production. There is only one uncontrollable factor of plant growth at Ngandjoek, and that is the rain, which here, as elsewhere, falleth when it listeth; consequently nothing else is to be expected than that the yield of sugar will rise and fall with the moisture supply. But if all else is provided for or guarded against, fluctuations of sugar yield should reflect, with constant fidelity, fluctuations of the rains, quite in accordance with the third universal principle of agrobiology described in our fourth chapter. That this is so is easily perceived from an inspection of the plantation records at Ngandjoek for the five-year period beginning in 1928, and as this story will doubtless come to the attention of critical experts we shall reproduce the proof.* The correlation factor between rainfall and sugar yield on this plantation is $+0.994$, and no mathematical statistician needs to be told that this correlation, being practically identical with unity, bespeaks practically absolute interdependence between the two phenomena. Knowing the amount of rain received during the critical growing season, the amount of sugar that will come through the mill is known within a negligible range of error. The regression equation is

$$X_1 = 14402 + 0.077891X_2 - 0.012265X_2$$

in which X_1 is the sugar yield in kilograms per hectare, X_2 is the rainfall in millimeters from Sep-

* E. Smit Sbinga, "Correlation between rainfall and sugar production of POJ 2878," *Archief voor de Suikerindustrie in Nederlandsch-Indië*, vol. 42: I, pp. 365-9.

tember 15 to December 15, and X_2 is the rainfall between December 15 and May 15. From this equation there are obtained the relations exhibited in Table IV.

TABLE IV.—CORRELATION BETWEEN RAIN AND SUGAR YIELD

<i>Crop Year</i>	X_1	X_2	<i>Sugar Yield Calculated Kg/Hectare</i>	<i>Sugar Yield Obtained, Kg/Hectare</i>	<i>Deviation of Calculated Result, %</i>
1928	401	1,194	16,065	15,990	+ 0.47
1929	396	1,032	16,146	16,078	+ 0.42
1930	262	1,251	14,911	14,928	— 0.11
1931	148	1,743	13,418	13,372	+ 0.34
1932	334	1,277	15,440	15,656	— 1.38

From this exhibit nothing could be clearer than that quantity of plant life and quantity of growth factor are perfect correlatives, and it further demonstrates that this perfect correlation can be and is being attained in large-scale commercial farming. Not by ordinary inexperienced farmers, certainly, and perhaps not by survivals among the old-line agronomists, but by men possessing the knowledge and the material resources for controlling the natural circumstances that confront them. The one circumstance that was left uncontrolled at Ngandjoek is here given as a sample of the proof that, in proportion as a multiplicity of growth factors is reduced to constancy, the result tends to uniformity, and that when only one variable is left the result is directly determined by this one variable. And when there are no variable factors? It goes without saying that the result then becomes in-

variable. Absolute constancy of sugar yield at Ngandjoek could not be attained solely because of the lack of an adequate supply of irrigation water. Were this available, the moisture factor could also be held constant and the yield of sugar could be calculated to within an average error of less than one per cent before the crop is planted, and more than a year before harvest.

By this it is intended to answer the question as to whether agrobiologists can attain clock-like precision on the open fields. It can be done, and as we have shown in another connection it may generally be done with a smaller outlay of cash or labor per unit of produce than is being achieved by agriculturists who are following traditional routine. Given perultra agrotypes, and healthy perfertile soils that are well watered either by irrigation or regular rain, the theoretical perultimate yields should be reproduced or closely approximated wherever the agrotypes are adapted to the average temperature of the locality. However, it will be brought out later that even if approximation to the perfect result is not closer than ten per cent, the discrepancy will be practically negligible in view of the great powers of perultra agrotypes.

Our exploration of the limits of the population problem may now be resumed; in this chapter we are engaged, in general, to show how many people may be sustained on the unit area of land when an effort is made to obtain the last possible ounce of food material; the question as to where and in what cases

such an extreme effort may have to be made does not for the moment interest us. Prior to starting off on the digression about "blueprint farming" we were considering what qualifications had to be made to the statement that one square mile of perfertile soil planted to a perultra agrotype will furnish the annual protein requirements of 32,640 people; the first qualification that was pointed out is that nothing is to be wasted, and the second is that the agrobiologists must work with clock-like precision.

The third qualification is that all the 2,080 pounds of protein contained in the perultimate crop of a perultra agrotype must be in a form that is directly and entirely digestible in the human stomach, and here we encounter what may prove to be a large deduction. Not all the protein synthesized by the common food plants is readily digestible. In the case of wheat, for example, 60 per cent of the total yield is straw, leaving only 40 per cent for the clean grain. The clean grain that would be yielded by a perultimate crop of wheat will contain 1,344 pounds of protein per acre, and the 736 pounds of protein contained in the straw could be recovered only with great difficulty. However, if the straw is efficiently fed to domestic animals and thus converted (at a large loss) into flesh or milk we might obtain an additional 150 pounds, making a total of 1,494 pounds of directly edible protein from one acre. When the necessary calculations are made it is found that the available protein from a square mile of perultra wheat

grown in a perfertile soil will meet the minimum protein needs of 23,774 persons for a year.

A fourth qualification is that the population must have other supplies of bodily energy in addition to the daily 50 grams of protein; under our postulate each average individual is to receive a total of 2,500 food calories per day. The 50 grams of protein which we allow him will furnish only 200 calories, so there remain 2,300 calories to be supplied in some other form. Besides containing protein, wheat also contains carbohydrates and fats in amounts such that the ratio of proteinous to non-proteinous food calories is as 1 to 6.1. By calculation it is found that if an individual gets all his calories from wheat he will be consuming 102 grams of protein instead of the prescribed 50 grams, and under this condition the number of people who could live on a square mile of annual perultimate crops of wheat shrinks to 11,315.

Remembering that we are now considering the matter solely as a question of limits, we may assign to perultra wheat a presumption of ability to support 11,315 persons per square mile, all deductions made. This is no inconsiderable result in itself, because 11,315 is approximately five times the density of population in the most thickly inhabited nations of the earth. However, even this result is predicated on the assumption that perultra wheat agrotypes are available for cultivation, but so long as we are merely considering the theoretically attainable limit it is not necessary at the moment to go into the circumstances under which this condition will be fulfillable. It may

further be noted in this connection that in this estimate no provision has been made for anything but food, and no allowance has been made for seed reserves or for a varied diet, except as regards the small amount of animal products obtainable by feeding the straw to stock.

CONCERNING "CALORIFIC DUTY OF NITROGEN"

The net result of the discussion thus far is that while one square mile of a perultra agrotype may be made to fabricate enough protein (if it were all directly available) to meet the needs of 32,640 persons, it may not at the same time furnish enough non-nitrogenous nutriment to make up the required 2,500 calories per capita; whether the agrotype can meet this condition will depend on its chemical composition, that is, on the relative proportions of protein and non-protein in it. Wheat will not fill the bill because its protein: non-protein ratio is 1: 6.1. If an agrotype is to supply the 50 grams of protein and at the same time 2,300 non-proteinous calories it must contain protein and non-protein in the ratio 1: 11.5.

It is thus evident that whether the practical limit density of population on the assumed basis will square with the theoretical limit depends vastly on the chemical composition of the agrotypes that are used. For the purposes of the present study it is therefore of prime importance to look into the composition of the principal food plants.

When tables of analytical data giving the compositions of vegetable food materials are examined it is

seen that the ratios of digestible proteins and non-proteins show wide divergencies from one species to another. Such data are shown in Table V. From this table have been omitted such components as ash, moisture, crude fiber, etc., and no account is taken of extractives in the offal.

TABLE V.—APPROXIMATE COMPOSITIONS OF VEGETABLE FOOD MATERIALS

	<i>Crude Protein, %</i>	<i>N-Free Extract, %</i>	<i>Fat, %</i>	<i>Ratio of Protein Calories to Non-Protein Calories</i>
Soy beans	36.5	26.5	17.5	1.8
Field pea	22.9	57.8	1.1	2.6
Navy bean	22.7	53.0	0.7	2.8
Peanuts, shelled . .	26.8	17.5	44.9	4.1
Oats	12.5	59.6	4.4	5.6
Rye	11.3	73.2	1.8	6.0
Wheat	12.5	71.2	2.1	6.1
Kaffir corn	11.1	70.1	3.0	7.0
Potato, white	2.75	22.0	0.1	8.0
Corn (maize)	10.1	70.9	5.0	8.1
Rice, polished	7.4	79.0	1.9	11.0
Potato, sweet	1.8	26.0	0.6	15.3
Arrowroot	1.6	29.9	0.2	17.2
Cassava, fresh	1.1	28.8	0.3	27.6

The point of chief present interest about this table is that it exemplifies what has been called "the variable calorific duty of vegetable nitrogen," which requires a little explanation. It will be recalled that when it is desired to ascertain the perultimate quantity

of life in a perultra agrotype, that is, the utmost number of pounds of vegetable substance it will yield on one acre of ground in one growth cycle, the numeral 318 is divided by the percentage nitrogen content of the agrotype in question, this arithmetical operation being indicated by the formula $318/n$. Now, this numeral 318 represents the maximum number of pounds of nitrogen that any agrotype theoretically may and all perultra agrotypes *do* resorb from one acre of perfect soil. That is to say, each and all perultra agrotypes, in the act of producing their perultimate yields, resorb 318 pounds of nitrogen, and consequently all produce 2,080 pounds of protein per acre. Therefore, all perultra agrotypes, regardless of the botanical class, family, genus or species to which they may belong, are equally efficient as producers of protein because they all produce the same amount (though not necessarily in the same readily accessible form). But while they all produce the same yields of protein, they differ enormously in the quantities of non-nitrogenous substances which they concurrently produce, though all may be growing in exactly the same soil and under the same sun. Thus, referring to Table V, we find such food plants as the soy bean storing in its seeds one protein calorie for every 1.8 non-protein calorie. From this low proportion of non-protein the ratio ranges up to 27.6 in the case of the cassava root. Evidently, the protoplasm of the soy bean is much more sluggish as an agent in the synthesis of carbohydrates and other non-nitrogenous constituents than the protoplasm of the

cassava; and without knowing the reason for this difference the agrobiologist dismisses it by saying that the efficiency of vegetable nitrogen as an agent for the fixation of the calorific energy of the sun is variable with the species.

In any case, here is a point of capital importance in the delimitation of the population problem which deserves to be particularly stressed.

Assuming that the food plants listed in Table V have all been bred up to perultra status, and solely for the sake of simplicity also assuming that the quantities and compositions of the waste portions of these plants are proportionally the same as of the edible portions, it is evident that, on the basis we have been using, a square mile of perultra soy beans will support less than half the density of population that would be supported by a square mile of perultra peanuts, which in turn will support about half the density that would be supported by the white potato. It is not until we come to rice that we find a ratio that closely corresponds to the postulated ratio of one part protein to 11.5 parts of non-protein calories. This vegetable is thus admirably adapted to supply the complete theoretical minimum ration for maintaining existence on a low level of comfort, such as is now being endured by congested Oriental populations.

The position of rice on this scale is noteworthy for another reason. It marks the point in the table that divides the food plants which have an excess of protein (from our standpoint) and those that have a de-

iciency of protein. An individual who drew his 50 grams of protein from the sweet potato would at the same time necessarily consume other materials that would raise his intake of calories above 2,500, and this would apply in still greater measure if he subsisted only on the cassava.

It is necessary to emphasize this distinction because in setting up a limit to population based on a fixed ratio of protein to non-protein it is presumed that there will be no waste of either. If the diet is based on wheat alone, protein will be wasted, because some of it must take over the function of non-protein, wheat being theoretically deficient in carbohydrates. If on the other hand the diet is based on the sweet potato, carbohydrate will be wasted, because some of it must be sacrificed in order to get at the required amount of protein; we say that carbohydrate will be wasted in this case because the individual is not supposed to need more than 2,500 calories, and any excess might be put to other uses. But if the diet is based on rice there will be practically no waste in either sense. Since the proportions of grain and straw in rice and wheat are about the same, and since rice (whole plant) contains the smaller percentage of nitrogen, one square mile of perultra rice would support 60 per cent more people on our basis than the same area of perultra wheat.

However, it is very well known that humans in general cannot well subsist indefinitely on a single foodstuff without falling prey to nutritional disorders, but it is quite possible to evolve schemes in which

two or more food plants may be combined to afford a varied diet and at the same time maintain the ratio 1: 11.5. Thus, an acre of perultra soy beans and 0.6 acre of cassava will together furnish the proper ratio, and the possible number of such combinations is large.

If the discussion were closed at this point the judicious reader would probably sum up as follows: Granting the existence of perultra agrotypes and admitting the possibility of harvesting annual perultimate yields of these super-efficient organisms, each fabricating 2,080 pounds of protein per acre, the attainment of a population density of 32,640 persons a square mile is still not a possibility because none of the agrotypes grown in the fields is directly and completely digestible as human food, so that when all deductions are made the actual population-sustaining values of a selected list of agrotypes are found to range from about 11,000 (perultra wheat) to about 18,000 (perultra rice) per square mile... no one agrotype can be made the sole basis of subsistence, but by planting a suitably chosen variety of crops, some rich in protein and some rich in carbohydrates, it will be possible to strike an average of about 15,000 yearly rations... this is considerably short of the figure 32,640, which is based on the apparent annual yield of protein, but it is still quite impressive when it is considered that, so far as known, there is no European nation having a population much exceeding 1,500 per square mile of arable land... such populations, if they cultivated their land to the limit set by Nature

for annual crops could supply themselves, not merely with a daily ration of 2,500 calories but with 25,000 calories each, which would give them a margin for comfort, luxury, extravagance and waste far beyond the present imaginings of European populations where the population density does not exceed 500.

However, the obstacles that have been cited as standing in the way of attaining the theoretical population density of 32,640 are in part factitious, in that they depend on limitations that have been tacitly introduced to simplify the preliminary discussion, and for the rest may be circumvented by exploiting circumstances to be discussed in the following chapter.

Chapter VI

EXPANDING THE PRIMARY LIMIT

THE PRINCIPAL conclusion reached in the preceding discussion is that perultra agrotypes growing on one acre of a perfertile soil will each fabricate in one annual crop a gross amount of protein sufficient to cover the minimum annual protein needs of 51 persons, which is equivalent to a population density of 32,640 per square mile.

We are here confronted with an absolute limit to population increase because, since no animal life is possible without vegetable protein, the limit to protein production is obviously a limit on animal life. The limit on protein production arises from the fact that no agrotype can usefully resorb more than 318 pounds of nitrogen from one acre of ground in one crop. But we found that this calculated population limit, 32,640 per square mile, is subject to discount because of circumstances that conspire to make a large proportion of the gross yield of protein unavailable for strictly proteinous nutrition. The result is that the actual number of persons (who under our postulates) can possibly subsist on the produce of annual crops is reduced to about 15,000 per square

mile, which is nevertheless a respectable figure in itself.

Were it not for the necessity of discounting the gross production in order to get at the available production the figure 32,640 could be identified as representing the ultimate Malthusian equilibrium, where the number of consumers is exactly balanced against the food supply at the minimum level of comfort, but in view of the discount the Malthusian end-point is seen to lie much lower. In either case the death rate must perforce be at least equal to the birth rate, because the ration allowed is supposed to be the smallest that will support normal life.

However, before deciding on a final or definitive location for either the theoretical or the practical points of Malthusian equilibrium, it will be well to consider whether our fundamental postulates are susceptible of amendment.

There is hardly any possibility of amending the postulate that the limit of protein production is 2,080 pounds per acre, because the nitrogen-resorption constant 318 is fixed by a universal law of Nature (any change in the value of this constant must be predicated on finding a more accurate value of the "effect factor" of nitrogen, which now stands at 0.122; see Appendix).

A change might be made in the postulate that the daily ration shall consist of 50 grams of protein and a total of 2,500 calories. But that may be left to those whom it may now or hereafter concern. For exposi-

tory purposes one reasonable if somewhat arbitrary assumption is as good as another.

There remains the postulate that the 2,080 pounds of protein shall be the product of one annual crop of a perultra agrotype growing on an acre of fertile soil. If instead of "one annual crop" we read "one crop cycle," the point of ultimate Malthusian equilibrium becomes a very resilient football. A crop cycle is that period of time comprised between the date of planting and the date of harvest. Under this new reading it becomes pertinent to examine some aspects of plant life not heretofore brought into this discussion.

We have already classified agrotypes as either perultra or subultra. The first of these classes includes those agrotypes that were originally endowed by Nature with the utmost of ability to vitalize inorganic nitrogen per unit of land surface, or have acquired this ability at the hands of the plant breeders. The second class includes those inferior agrotypes that are still held down by genetic complexes which keep them from displaying the perultimate quantity of life.

For present purposes it is necessary to distinguish those characteristics that are common to all perultra agrotypes from the characteristics that are not possessed in common.

A common characteristic of all perultra agrotypes is that when grown in a fertile soil they each fabricate an amount of protein which, according to the best information available to the agrobiologists, is

about 2,080 pounds per acre. But along with this common characteristic goes an enormous variation in the "calorific duty" of the nitrogen usefully resorbed by these organisms, so that while all are fabricating the same amount of protein, one perultra agrotype may fabricate up to fifteen or more times as much non-proteinous substance as another.

A further and no less important difference is that the vital energies of plants are affected by different time factors which, like all other genotypic characters, are constant and distinctive of the species. Every agrotype, whether perultra or subultra, has a certain normal crop cycle, or life period. This period may be a matter of weeks with some perultra agrotypes, and of years with others, yet the end-result is the same so far as the final quantity of protein is concerned. The practical result is that an active agrotype may produce two perultimate crops while a more sluggish agrotype is producing one. This difference in tempo is due to the fact that the green coloring matters of plants, chlorophyll, differ in their reactivities, that is to say, in the speed with which they accomplish the union of carbon dioxide with water to make the sugars from which all vegetable tissues are compounded. This activity of chlorophyll is not dependent on amount of leaf surface; some plants with few and small leaves are far more active than others with abundant foliage.

THE THREE SCALES OF PLANT LIFE

At this point the three scales on which the vital energies or quantities of life of agrotypes are measured may be formally identified.

I, the ABSOLUTE SCALE, which is applied to different phases of the same agrotype (varieties of wheat, for instance). On this scale the 100 per cent mark is given by the quotient of the formula $318/n$; yields of perultra agrotypes reach this mark, those of subultra agrotypes fall short.

II, the CALORIC SCALE, on which perultra agrotypes of different species (as corn, potatoes, etc.) are compared on the basis of their percentage contents of nitrogen, or protein/non-protein ratios.

III, the TIME SCALE, on which the basis of comparison is the length of the crop cycle.

The units on these three scales are natural constants, inherently characteristic of the individual agrotypes. For purposes of the science of population there may be added a NUTRITION-VALUE SCALE which is compounded of all three of the natural scales, and on which agrotypes may be rated according to their population-sustaining values per unit of time and area. In placing an agrotype on the nutrition-value scale it may happen that an unfavorable position of the agrotype on one of the natural scales will be more than compensated by favorable positions on the other two scales.

All farmers and gardeners are aware that some varieties of plants are "earlier" than others, and ad-

vantage is taken of the fact to obtain a succession of vegetables, fruits and flowers during the summer season. Agrotypes with short crop cycles are much sought after, for several reasons. One is that the produce soon comes on the market and thus commands a high price, due to shortness of supplies. Another is that quick-maturing species can be grown in climates where the number of frost-free days is limited. Obviously, a wheat agrotype with a crop cycle of 90 days can be grown farther north than one having a crop cycle of 120 days. The wheat breeders have some notable accomplishments to their credit in this line; by creating such short-lived strains of wheat they have enabled a flourishing civilization to spread over hundreds of thousands of square miles of otherwise inhospitable Canadian plains, and according to latest accounts the Russian geneticists and breeders are in the way of accomplishing the same thing with the white potato.

The point here is that the crop cycles of perultra agrotypes are not necessarily limited to one in a calendar year, and in so far as shorter crop cycles allow of a greater through-put or turn over from the same area of land, the limit of saturation of the land with population is correspondingly displaced. Thus, if two perultimate crops can be obtained in the same growing season the theoretical saturation limit is raised from 32,640 to 65,280 persons per square mile; and if by any chance it becomes possible to produce three such crops the theoretical limit becomes 97,920 persons per square mile. The corresponding new

practical limits, using the same basis as before, are increased from 15,000 to 30,000 in the one case and to 45,000 in the other case. How many crops may be obtained in the same growing season will depend, in the first instance, on the number of frost-free days, but primarily the turn over from a given area of land depends on the photosynthetic energy of the agrotypes per unit of time. There are numerous species of plants that have life cycles as short as two months; and in so far as these may be of value as food or other agricultural raw materials it is conceivable that as many as four crops could be obtained in the tropics or subtropics, with corresponding effect on the theoretical and practical limits to population.

Thus we find that, in so far as it is possible to jam more than one crop through the same growing season, the saturation limit to population may be raised to or above our initial or primary figure of 32,640 in disregard of the requirement that only perultra agrotypes be grown, and also in disregard of the unfulfillable condition that the produce be completely digestible. Suppose that a subultra agrotype, with a suitable protein/non-protein ratio, has only 80 per cent of the perultimate quantity of life and is only 65 per cent digestible, but is capable of making two crops a year. These two crops together will have a population-sustaining value equivalent to 104 per cent of our primary figure, giving us in fact a calculated density of 33,945 per square mile. This means that quantity of plant life on the absolute scale may

be of less practical importance than quantity of plant life on the time scale.

The reader will remember that we are here mainly interested in the ultimate limit to the ability of land to support population, and for this reason we have been proceeding on the assumption that agricultural production will be engineered primarily for the purpose of supplying the population with as much directly edible vegetable food as possible. In other words, we have been contemplating the attainment of a state of Malthusian saturation where the population is strictly vegetarian and where no provision is made for foods of animal origin except such as might be obtained by feeding the humanly inedible offal to domestic animals. While it is certainly desirable thus to determine the limit of existence in order to have a mathematical reference point for a science of population, it is clear that no population would be content to exist at the limit, or to be deprived of animal foods like milk, eggs or beef. The production of such foods makes large demands on the land; to obtain one pound of prime beef means the sacrifice of four or five pounds of vegetable food materials that might be directly consumed. This circumstance will have to be taken into account whenever it becomes a practical matter of calculating the ability of a marooned group or nation to live at home on its own resources. It is not our present business to make extended calculations along this side line, but it will be of interest to indicate how a congested population might obtain

larger allotments of protein and other digestibles derived from a liberal supply of animal products.

THE SHORTENED PROTEIN CYCLE

There are various devices for speeding up and enlarging the through-put of protein from the unit area of land; the reader may perhaps be interested in one which is simple enough to have been discovered half a century ago, but has come to general notice only within the last half dozen years.

As we have repeatedly stated, the limit of nitrogen resorption by a perultra agrotypic in one crop cycle on an acre of perfect soil is fixed by Nature at about 318 pounds. Now, the interesting fact is that most of this nitrogen is resorbed and transformed into protein in the early stages of growth; it seems that the young plants make it their first business to gorge themselves with nitrogen and to fabricate therefrom the protoplasm they will need later on as a tool for the fabrication of their finished products, chief among which are stems, fiber, carbohydrate and other non-nitrogenous materials. For this reason the substance of young plants contains, on a percentage basis, much more protein than the same plants at maturity; and not containing so much cellulose or fiber, is much more nutritious and digestible. Hence, if the young plants are mowed or harvested when about half grown they will contain more than half of the protein they would yield if allowed to grow to maturity. The practical effect of this is to very considerably shorten the crop cycle—that is, the protein cycle—because a

rapid succession of immature crops rich in protein may be taken off the fields while an ordinary crop would be maturing; and it may turn out that such partial crops of even subultra agrotypes may together resorb very considerably more than the 318 pounds of nitrogen in one year even on soils that are less than perfertile. How it works out in practice may be illustrated by the routine of a midwestern American farm:

"Wheat is planted August 15 to September 1; the young plants are clipped just before they joint, which with optimum temperature and moisture conditions is 18 to 31 days after planting. On the best soil it will yield 1,000 to 2,000 pounds of dry hay, testing 30 to 40 per cent of protein. Sometimes there may be as many as three cuttings before freezing weather.

"This same seeding will now stand the winter and can be cut one to three times in the spring. About May 15 the wheat is plowed under and the field planted to Sudan grass, and if irrigated yields a ton of dry matter every 10 days until time to plant wheat again for another cycle."

On this farm in this manner it is possible to obtain seven tons of wheat and Sudan hay containing 4,000 pounds of protein and a corresponding amount of carbohydrate from one acre, which is twice as much as the perultra phases of either of these agrotypes would yield when handled in the ordinary way. It is true that the product is hay, which though of a very superior kind is not usually consumed by humans, but is admirably adapted for conversion into milk and meat, and is cited here merely to show the enor-

mous possibility of obtaining increased supplies of protein directly from the land.

This new idea in practical agrobiolgy deserves a more extended notice, because it is one of the most profoundly important discoveries ever made in applied plant biology—far more significant economically than all the exploits of the late Luther Burbank that have received a thousand times the publicity. Consider for a moment what an aggregate crop of young hay, amounting to seven tons an acre per year, with 13 per cent of digestible protein and a starch equivalent of 66½ per cent, will mean in animal husbandry. These seven tons of hay, which are greedily eaten by all kinds of stock, including pigs and poultry, are the full nutritive equivalent of 233 bushels of Kansas wheat or 250 bushels of Iowa corn—five times the nutritive value that a good Kansas wheat farmer or Iowa corn grower obtains from one acre in a good crop year. These seven tons of young hay, when efficiently handled in the feed lot, can be turned into 1,890 pounds of baby beef or 2,680 gallons of milk, representing, in much-prized animal products, twice the poundage of an average acre yield of wheat in the United States (15 bu. per acre). When this easy method of obtaining abundant supplies of concentrated and well-balanced stock feed comes to be generally adopted, a steer can be raised and fattened on the crop of half an acre of land; and beef, eggs, butter and milk, now relatively the most expensive of all foods, should become even cheaper than bread. Applied to sheep husbandry, under this method of hay-

making wool should become at most no more expensive than cotton. (But we hardly need expect this abundance until we have first produced a crop of agricultural administrators having both the capacity and the wisdom for evolving a social-economic mechanism that will make these enormous and easily exploitable sources of agricultural wealth really accessible to the common man.)

The credit for this epochal discovery seems to belong to Professor H. E. Woodman, who about 1926 became interested in knowing the composition and nutritive value of grass as actually eaten by grazing animals; this was a point that had not theretofore excited the curiosity of agricultural chemists. The results of Woodman's investigations have been confirmed by scientists and practical agrobiologists in many countries, including (as we have mentioned) the United States. We may now reasonably expect to see the well-managed stock farms of the future take on the appearance of vast lawns, which will be kept well-watered and fertilized and frequently mowed for the nutritious and protein-rich young grass, which will be dried and stored for use throughout the year. Corn fields will largely disappear because even perultra corn, in so far as existing varieties require a full growing season for one crop, can hardly compete with lawn grass in quality or quantity of feeding values.

This discovery of the short protein cycle opens new possibilities for the agricultural development of regions now regarded as seriously handicapped by climatic limitations. Since one of these cycles need not

consume much more than four weeks, a region having only a very brief rainy season, or a far northern region with a short growing season, can produce food values on a par with the best that average agriculture anywhere is now showing.

INDIRECT PRODUCTION OF PROTEIN

It remains to notice an indirect but impressive method of getting around the limitation that no more than 2,080 pounds of protein can be produced directly on one acre in one full crop cycle of any agrotype. This expedient is founded on the fact that the limitation referred to applies only to the higher orders of plants, i.e., those like corn, potatoes, or beans, which are cultivated in the fields and are fixed to the soil in which they have their roots; such plants obtain their oxygen and carbon dioxide directly from the air and fabricate their protein from the mineral nitrogen of the soil. There are other, more lowly members of the vegetable kingdom that flourish in quite a different habitat. Among these are the microorganisms known as the yeasts; these, like the higher plants, have the ability to synthesize protein directly from mineral or inorganic nitrogen. They may also take some oxygen from the air, but for their carbon they must depend on sugars, or what is known as fermentable materials, which themselves are produced by just such plants as the farmer cultivates. What makes this circumstance interesting and important from the standpoint of the population problem is that while any and all of the field agrotypes that may

be cultivated by the farmer are strictly and uniformly limited by Nature on the amount of protein they may fabricate on a certain area, no such uniform limit is imposed on them as regards the amount of carbohydrate (fermentable material) which they may concurrently produce, and in some cases the amount of carbohydrate yielded by a vigorous field agrotype is truly enormous. This being the case, if Nature allows the production of large amounts of sugars per unit of area, and if this sugar can be turned into protein, the limit on direct protein production may be outflanked, so to speak.

The case of the sugar cane will serve to illustrate what may be said in this connection. This agrotype is among those most distinguished by a large production of non-nitrogenous substance, its ratio of protein to non-protein being close to 1:50. In its perultra phase the sugar cane contains about 0.33 per cent of nitrogen in the dry substance, so that by the formula $318/n$ its total production of dry substance in one crop cycle on one acre of ground is 96,300 pounds, and this yield is known to be closely attainable under the conditions of open field practice. Of this 96,300 pounds of dry sugar-cane substance about 48,000 pounds is directly fermentable sugar (sucrose plus glucose); another 17,000 pounds is cellulose, which by well known chemical processes is transformable, without loss, into a mixture of sugars that are also fermentable. This gives a total of about 65,000 pounds of fermentable material from one acre in one crop cycle.

Now, when these 65,000 pounds of fermentable material are offered to certain kinds of yeast under certain well known and thoroughly understood and technologically practicable conditions, for every pound of sugar put in operation there is produced half a pound of yeast (dry weight) containing 50 per cent of its weight of protein, besides certain amounts of other digestible constituents. The effective result is a yield of one-quarter of a pound of protein for every pound of sugar, so that in this indirect manner the perultimate yield of protein per acre in one crop cycle, instead of being only 2,080 pounds (and much of this inaccessible to humans) is 16,250 pounds, and practically all of it is digestible both by men and animals. This is close to eight times the highest possible yield of protein obtainable directly from the land in one crop cycle.

Reducing the above described result to the basis of one square mile and still allowing 50 grams of protein per person per day, and also considering that the effective crop cycle of the sugar cane is eighteen months, we find that one square mile of such an agrotypic as the sugar cane will cover the minimum protein needs of 170,000 persons (in round numbers) for one year.

The technical conditions for making protein from sugar are quite simple. They involve first, the choice of the most suitable forms of the yeast organism, *Saccharomyces*. The strains that come into consideration here are not the kinds used in baking or in the production of beer and wine, but the so-called "wild"

or "comb" yeasts which sometimes take possession of carelessly conducted fermenting establishments, where they are considered great nuisances because they produce little or no alcohol or carbon dioxide gas, for which latter reason they are valueless for baking purposes. But they multiply with extraordinary vigor and are very efficient producers of protein. All they need is a sugary solution which also contains the same mineral nutrients that are applied by farmers to the crops in the fields: nitrogen, phosphate, potash, lime, etc. The operation is conducted in a large tub into which are blown large quantities of air, and requires only a few hours' time. When all the sugar is used up the crop of yeast is simply filtered off, and then only requires to be dried or cooked to become a fit basis for the proteinous nutrition of man and beast.

This idea of using yeast as a source of protein for food purposes began to develop about 1908, when Henneberg first noted that yeast organisms could supply their nitrogen requirements wholly from inorganic sources, and during the Great War the idea was seized upon by the Germans when they found themselves cut off from imports of concentrated food-stuffs like oilcake, etc. Huge factories were built, and had it not been for contingencies which the German officials neglected to provide for, these factories might have gone a long way toward sustaining the Central Powers in that mighty conflict. With the return of peace the idea was allowed to slumber for a time, but with the Germans again in the way of being reduced

to the practice of autarchy it has been revived in factories that use waste wood as a source of fermentable sugars. This wood is first digested with acid under pressure; this operation hydrolyzes the cellulose of the wood into sugar, and it then only remains to neutralize the acid with lime, add the seed yeast, and proceed in the described manner.

What might be done in the way of sustaining a population on the basis of such an agrotype as perultra sugar cane may be deduced as follows: This agrotype in its perultra phase fabricates the same amount of protein as any other, namely, 2,080 pounds, but this direct yield of protein is distributed through such a vast mass of cellulose and other non-nitrogenous matter that it is practically inaccessible as food, and may be ignored. One acre of such sugar cane yields, as we have figured above, 65,000 pounds of carbohydrates, from which 16,250 pounds of protein may be manufactured in the manner described. When employed as a component of our unit ration this 16,250 pounds of protein will validate for food purposes the carbohydrates produced on 2.87 other acres of the same agrotype. On completing the calculation it is found that the number of persons who can be supplied with a wholly edible minimum annual ration from one square mile of perultra sugar cane is 69,600. The figure 32,640, which represents the theoretical primary limit to population density imposed by the limit on direct production of protein, is thus effectively by-passed.

However, this example is a little faulty in that

sugar, although quite welcome in a certain proportion, is not well adapted to serve as the only source of carbohydrate nutrition, but this objection is overcome when the diet is compounded along with starchy and oily foods from other agrotypes. Numerous combinations are possible, some of which will bring the limit below 69,000, while others may conceivably increase it; details may be left to when and as concrete cases have to be worked out. The main thing with us at the moment is to clarify the principles by which the point of saturation with population may be computed for any given situation.

From the foregoing it will be plain that the saturation limit of population may take an infinite series of values, because the agrotypes on which most agricultures are based show an infinite variety in their quantities of life and other genotypic characters. The limit on population density will have about its lowest values when agriculture is based mainly on the legumes, because these agrotypes, while percentually very rich in protein, are generally ineffective as fabricators of the carbohydrates needed to make up the supplemental food calories of a balanced ration; their overall quantities of life are small. The cereals can sustain more animal life than the legumes, because they themselves have more life; they fabricate quite as much protein as the legumes, but they have a larger endowment of vital energy for trapping and storing solar energy in the form of non-proteinous substance. But even among the cereals we find a graduated scale of photosynthetic power; though all

may fabricate the same quota of protein, some produce not enough carbohydrate to constitute the adopted minimum ration, and others produce more than enough. The usefulness of all agrotypes is affected to a larger or smaller extent by the fact that not all their food values are accessible; hence the figure 32,640, which would be the natural limit to population based on direct annual crops of protein, is unattainable with any single agrotype but may be reached and even surpassed by a suitable combination of agrotypes. And beyond the limit imposed by Nature on direct production of protein in the fields lies the wider limit opened by the possibility of converting carbohydrate into this scarcer and more valuable food constituent.

Naturally, the limit of saturation with population will take its highest value where agriculture is based mainly on agrotypes whose nitrogen is capable of the largest "calorific duty." These are the agrotypes that have the ability to store up immense quantities of carbohydrates in their juicy stems, or in thick, fleshy tubers or roots; such agrotypes are the sweet potato, the Jerusalem artichoke, the cassava, the sugar beet, the carrot, the sugar cane, etc. By producing enormous quantities of fermentable materials these mighty organisms provide the means for enormous indirect yields of protein.

LOOKING BEYOND THE KNOWN LIMITS

However, there is still left open the question as to what is the perultimate, the *ne plus ultra*, limit

to saturation of the soil with population. This final, unsurpassable limit to the numbers of man on this earth will not have been reached until there shall have been discovered and put to use that or those perultra agrotypes whose nitrogen percentages are the smallest known, whose quotients of $318/n$ —expressing the maximum yield per unit of area—are the greatest known. But even when all the *existing* superefficient agrotypes have been sought out there still remains the possibility of continuing the upward displacement of the saturation limit by finding new agrotypes with still lower nitrogen percentages and therefore with wider margins of life.

This further prospect depends on the fact that the nitrogen percentage of agrotypes is not necessarily an immutable character; it is indeed fixed and unchangeable in any pure-bred plant genotype—so long as such a genotype is prevented from interbreeding with other strains. Let interbreeding occur to change the genetic complexes of the offspring, and then anything may happen—that is, the hybrids may have the same, a lesser, or a greater quantity of life than either or both the parents. This is precisely what geneticists and plant breeders are doing: making crosses and, according to the fall of the dice of life, preserving the new forms having the most life. Generally it turns out that where more life is gained, nitrogen percentage drops; or, to say the same thing in another way, the lowering of the nitrogen percentage is a sign that quantity of life is being gained.

Consider the history of the sugar beet, which

started a hundred years ago as an insignificant root with much nitrogen and little sugar and has now been bred to contain less nitrogen (on a percentage basis) and much sugar; and the end is not yet in sight. Year by year the breeders succeed in lowering the nitrogen percentage a little and are correspondingly raising the potential yield of useful material per unit of area. Where is this to stop? No man knows. Nothing is yet in sight to indicate what is the lowest possible percentage of nitrogen in sugar beets, or for that matter in any other agrotype. The present sugar beet in its near-perultra phase contains about 0.84 per cent of nitrogen in the dry substance, and there is compelling reason for expecting this percentage to be further reduced. The most advanced phases of the sugar cane have about 0.33 per cent, and if the cane breeders succeed in their project of crossing *Saccharum officinarum* with *S. robusta* we may expect new varieties with increased quantities of life. We have just seen that perultra sugar cane with 0.33 per cent of nitrogen can produce the complete minimum ration for a population of 69,600 to the square mile. Suppose that the cane breeders produce another perultra phase with only 0.15 per cent of nitrogen; the already fabulous figure 69,600 would be more than doubled.

In other words, the upper limit to the calorific duty of vegetable protoplasm is still undiscovered, and until *this* limit is established man will not know the perultimate limit to his possible increase on the earth.

Even so, when, if ever, men succeed in implanting in their agrotypes the very largest possible quantity of life that any agrotype can display in one crop cycle, the quest for the figure that represents the final, the ultimate, the impassable limit to population density will be only well begun.

As a matter of fact, plant life has not one, but three boundaries, each independent of the other. As we have pointed out before, the life of plants in the fields is measurable on three different scales—the absolute scale, the caloric scale and the time scale. On the absolute scale we measure the total quantity of vegetable substance produced in a full crop cycle, regardless of the number of days or months occupied by this cycle; if at maturity the yield of the agrotype corresponds with the formula $318/n$ we call the agrotype *perultra* and give it a rating of 100; if not, we call it *subultra* and rate it according to its performance. When we measure quantity of plant life on the time scale we divide the total yield (whether *perultimate* or *subultimate*) by the number of days taken to produce it; this shows what the agrotype has done in the unit of time. The results of such measurements have been to show that two agrotypes occupying similar positions on both the absolute and the caloric scales may exhibit very different quantities of life when measured on the time scale; and it is clear enough that, other things being equal, the agrotype with the shorter crop cycle is the more valuable from the viewpoint of the population problem.

The existence of these three quantitative scales of

plant life makes it possible for the plant breeder, while he is increasing the value of his agrotypes by elevating their positions on the absolute and the caloric scales, to concurrently still further increase their value by shortening their crop cycles. When these three independent lines of the induced evolution of useful plants finally reach their respective ultimate terminals, the perultimate limit of saturation of the soil with population will have been found: when the life cycles of perultra agrotypes with the lowest possible percentage of nitrogen have been compressed into the shortest possible space of time.

What this shortest space of time may be we do not know—not any more than we know what is the perultimate minimum nitrogen percentage of any agrotype. For an exploration-minded world here are two fields inviting a larger share of that adventuring for knowledge which sends costly expeditions to map icy wastes, to dig up the bones of long-extinct monsters, to resurrect buried civilizations, and spends tens of millions of dollars to get a little better look at the stars, all with no more hope of tangible return than the satisfaction of intellectual curiosity. Without belittling the vast terrain already conquered for humanity by the agrobiologist, what he has achieved may be relatively small in comparison with what might yet result from a further, more systematic and intensive exploration of the three boundaries of plant life, with the prospect that every advance, however small, will be a direct contribution to the security and comfort of man's place in Nature.

Irrespective of how future research on the boundaries of plant life may turn out, and considering only the solid ground that has been won, it may be taken for granted that when everything has been done that can be done and everything saved that can be saved, and from among the various values that might be computed for a practical limit to population density selecting one that is little open to an imputation of exaggeration, one square mile of well managed land should provide approximately 40,000 people with our calculated minimum ration. But nowhere at the present time is there even a remote approach to such a pressure of population on the soil. The densest population that now exists by its own agriculture perhaps does not equal or much exceed 2,000 per square mile of arable land. Supposing such a population to be existing on 2,500 food calories per day, if its agriculture were expanded as herein indicated the daily allotment could be increased to 50,000 calories, which would provide every individual with a very broad margin for comfort, luxury and waste in the matter of agricultural raw materials.

THE QUESTION OF MEANS

But what may not be clear to some readers is the relation of human effort and material resources to such a prodigious outpouring of agricultural raw materials from the soil. Supposing one square mile of arable land is actually being worked to produce food calories for 40,000 people, how much labor, water, fertilizer, etc., must be put into the operation?

The answer, in general terms, is that to plant, nourish, water, and cultivate a perultra agrotype in the act of producing its perultimate yield will require practically no more labor, material or investment than to care for the most inferior subultra agrotype that is being made to do the best it can. It is one of the curiosities of agrobiologic science that all agrotypes whatsoever, regardless of their positions on either the absolute, the caloric, or the time scales of vital power, require soil of exactly the same degree of richness if they are to produce their respective ultimate yields; in plain terms, a soil need not be made much richer to support 40,000 people per square mile under the new agrobiology than to support a population of 2,000 under the empiricism of the old ineffective but still largely prevailing agronomy. The difference here is the difference between coördination of effort and what practically amounts to chaos, between an understanding of the balanced harmony that must prevail among the dozen factors that come into play on the one hand, and on the other the uncertainty and groping that comes from non-use of scientific yardsticks. To recall what was said in another chapter, any soil that is furnished with eight or more of each of the essential factors of plant growth is as rich as need or can be in any event, and it costs no more to furnish these units for one kind of crop than for another. Under normal conditions all agrotypes, regardless of their individual peculiarities or their actual yielding abilities, make practically the same initial demands for the material means of plant

life.* The same applies to labor operations. It costs no more to plow a field for the most vigorous perultra agrotype than for the most inferior subultra agrotype of the same species (corn, wheat). No more time or labor need be consumed in the subsequent cultural operations in the one case than in the other, nor will it cost more to police against diseases and pests. About the only imaginable difference in cost between good and poor crops will lie in the extra labor of hauling off the more abundant produce.

Again, there is the question of supply of materials. In order that soils may be made and kept perfertile it is necessary to stock them with all necessary fertilizing materials and then to make good the amounts withdrawn by the crops or lost in various ways. As regards nitrogen, the fertilizing element that is consumed in the largest amount, it is literally as free as air, requiring only machinery that can be set up anywhere to take it from the atmosphere. As regards phosphate, conditions differ in different parts of the earth. The United States possesses enormous deposits of phosphate rock, whereas some other nations have none; an isolated nation lacking such resources must of necessity import phosphate, unless it carries autarchy to the point of working a fixed supply in a closed cycle. Most of the phosphate consumed in agriculture finds its way into the bones of animals or into sewage, and in either case is subject to recapture for return to the soil. It is all a matter of

* The scientific basis of this general uniformity in the requirements of all agrotypes is set forth in the Appendix.

planning and organization. Potash supplies are much more abundant than phosphates, and occur either as potash deposits in association with salt beds or as volcanic rocks that easily give up their potash; if worst came to worst an existing stock of potash could also be worked in a closed cycle. There is practically no existing nation without abundant supplies of limestone, and the other necessary mineral elements of plant nutrition are needed in such relatively small quantities, or are locally so abundant, that their procurement will offer no special difficulty anywhere.

No consideration of the agricultural resources of a nation will be even approximately satisfactory without account being taken of its water supply, for water is the one element that bulks largest among the dozen indispensable factors of plant growth and yield. It is superfluous to remark that agriculture cannot reach its highest estate where the moisture supply is not both adequate and regular. As regards adequacy, it is a fact that (good management presumed), on the average, to produce one pound of dry vegetable substance it is necessary for the growing plants to transpire through their leaves approximately 300 pounds of water. The amount of water required by a perultra plant will depend on what its perultimate yield is. In the case of an agrotype whose perultimate yield is 25 tons of dry substance per acre, about 66 acre-inches of water will be required for transpiration alone. Less productive agrotypes will require less, but striking a general average and making allowance for direct evaporation, seepage, and run-off, it may be

assumed that a moisture supply equivalent to six feet or 72 inches of rainfall will be necessary to support an agriculture that is working at the limit of efficiency. It should not be overlooked that the rainfall must not only be adequate as to total inches of precipitation, but also that the moisture must be presented to the crops in a continuous supply, i.e., without the occurrence of prolonged drying out of the soil. Any nation that intends to insure itself against want by putting its agriculture on a solid agrobiologic basis must of necessity make sure that its supply of agricultural water is both properly conserved and correctly used—requirements that are generally not too difficult to be met.

A cursory examination of the rainfall statistics of the main centers of Occidental civilization shows that the average annual precipitation in Europe, for example, is very appreciably less than 72 inches, the average being nearer 40 inches. Superficially considered, this would seem to reduce the possibilities of agricultural production to about half of the perultimate.* But the rain falls on mountains and hills as

* However, water, like all other growth factors, is subject to the law of diminishing increments, as shown in Table III. The 72 inches here spoken of represent the *limit of desirability*, where additional units are used to give very small increases. A limited supply of water, if efficiently used, can be made to yield relatively handsome returns. For instance, in 1932, Waldron in North Dakota, following a series of four drought years that left the subsoil very dry, obtained yields of wheat up to 48 bushels per acre from a total rainfall during the growing season of only 6.63 inches! Naturally, this requires optimum conditions in all other respects.

well as on fertile plains. No nation expects to cultivate every square foot of its territory, and it is only a matter of intelligence and engineering to conserve water that is now wasted for use on the fields. In any case, it is an inescapable necessity for an isolated nation that resorts voluntarily or involuntarily to autarchy to achieve its agricultural independence of the products of foreign soil. One of the most glaring distinctions between the ordinary farmer and the creative agrobiologist is that the former is indifferent or neglectful of the moisture factor and leaves his crops to what falls from heaven, whereas the latter insists on a well-balanced closed system in which each factor is present and acting in due proportion. If maximum yields are to be obtained and water does not come of itself on the fields in due and regular amounts, it must be brought thereon.

If agrobiology is to fulfill the mission which we see for it, namely, to make it impossible for isolated or hard pressed nations to be starved, the group involved must make arrangements for the rational utilization of all appropriate resources in its possession; and although this may involve some trouble and expense, there is no imaginable case where it cannot be accomplished with far less sacrifice than will be involved in the hazards of predatory enterprises against other groups. Again it is only a question of organization and planning. Surplus rain water that runs from waste places can be impounded against the time of need. It has been done and is being done all over the world, even in the United States where

ordinary agriculture has been disastrously overexpanded, and where hundreds of millions of dollars are being expended in the erection of great irrigation works—presumably to produce more crops in the dryer regions so that production may be restricted by plowing up crops in the wetter regions. Such enterprises cost a good deal, but this writer has yet to observe a case where a well-balanced and well-managed irrigation project has not greatly increased yields and lowered unit costs. In other words, intelligent management of the water factor in agriculture never fails to justify itself.*

The water problem as it affects the agriculture of a nation that has to live at home because it has little to exchange for the products of other nations has another angle that deserves consideration in estimating its resources. This is that water is required in the daily life of urban populations as well as for agricultural purposes. Consider the city of Greater New York, whose 7,000,000 people use an average of 100 gallons of water per capita a day. This represents the capture from water sheds covering about 900 square miles, mostly untillable land. This urban water is equivalent to a depth of six feet on an area of 200 square

* Quite naturally, it is possible to mismanage irrigation projects, just as it is possible to mismanage any human undertaking. Numerous irrigation enterprises have failed disastrously, primarily because other factors were not brought into line with the increased moisture supply. Even at this late day, some farmers and reclamation experts have not got it into their heads that crop yields depend on *all* the factors of plant growth.

miles, which is sufficient to produce annual per-ultimate crops that would maintain this great population on our minimum ration. The point is that a dense population may require as much water for the ordinary purposes of life as would suffice to maintain the agriculture that feeds it. On this basis equal areas would have to be available to supply water for house and for farm use. But more than half of urban water is generally run to waste and with it the elements of fertility extracted by food crops from the soil. If no exceptional engineering difficulties present themselves it should cost little more to recapture (where necessary) this urban water and return it to the fields than it has cost to collect and distribute it as drinking water in the first place.

AGROBIOLOGY AND CLIMATE

We have developed the foregoing argument to show that the water problem is not necessarily a bar to an adequate agriculture in even the most densely populated regions.

It now remains to discuss the relation between climate and agricultural production from the standpoint of the population problem. The main elements of climate from the agrobiologist's viewpoint are rainfall, insolation (sunlight) and warmth (temperature). Wherever one of this triad is lacking or deficient agriculture is correspondingly depressed. The moisture question is susceptible to management, in that water can be taken from one place and led to another. Sunlight and warmth cannot be thus picked up and

carried about, and as to them the matter must be managed indirectly. It is necessary first to consider what is meant by a deficiency of warmth in plant biology. To illustrate, people in the tropics can obtain sugar from the sugar cane, but this agrotype cannot grow where the temperature is below 70° F.; the sugar cane cannot therefore be grown in the temperate zones, but the people of those zones may obtain their sugar from the sugar beet, which can flourish at temperatures much below the minimum endurable by the sugar cane; in other words, a deficiency of warmth in the agrobiologic sense is purely relative; what is not enough warmth for one agrotype may be quite sufficient for another. Again, it is often supposed that, because the tropics are so abundantly supplied with light and warmth, vegetation processes must necessarily proceed there more intensively than in the cooler parts of the earth, but to make such a supposition is to repeat the error into which some plant biologists as well as plain farmers have been known to fall: of locating the springs of the energy of plants in the outer circumstances instead of within the plant itself. The genotypic characters of plant genotypes are strictly internal; they depend solely on innate genetic complexes that are either adapted or not adapted to particular environments; the length of the frost-free period of the year may limit the duration of the crop cycle, but the environment itself has otherwise no primary influence on the position of an agrotype on either the absolute, the caloric, or the time scales of quantity of plant life. Thus, again to compare the

sugar cane and the sugar beet; the former flourishes only in the tropics where it has a crop cycle of eighteen months and in its perultra phase produces about forty-eight tons of dry substance; the latter flourishes in the temperate zones under much lower temperatures, where it has a crop cycle of seven months and in an equivalent phase is good for eighteen tons of dry substance; the average monthly production of dry matter in both cases is about the same, which shows that photosynthetic energy on the time scale does not necessarily depend on degree of warmth in the growing season. By choosing agrotypes that are able to make rapid use of low grade thermal energy there will be no reason for supposing that any of the present centers of civilization will not have enough of such energy for its agriculture.

The actual supply of agricultural warmth is worth a little further discussion. According to a calculation obligingly made for the author by Dr. C. G. Abbot of the Smithsonian Institution, the average quantity of solar heat received during one day of twenty-four hours on one acre of ground during the crop season between April 20 and October 10 along the 40th parallel of North latitude amounts to 30×10^6 Kilo-gram Calories.

The agrobiologic significance of this datum will appear when it is considered along with the thermochemical data of vegetable matter. By far the greater part of the dry substance of plants is made up of cellulose, starch and other carbohydrates, fats, proteins and lignins. From the thermochemical stand-

point all these are definite chemical substances, and have been synthesized by the plants in accordance with the principle that when a complex compound is formed from simpler ones a certain amount of heat, known as the heat of formation, is locked up in the new compound. That is, when carbon dioxide and water are combined in the green chlorophyll cells of the leaves to make sugars, etc., a certain amount of heat must temporarily disappear, to be given up later when the substance is burned or otherwise consumed. Plants as a rule do not generate heat within themselves as animals do, and the heat they need must come from their surroundings, which means, ultimately, the heat of the sun. The average heat of formation of one gram of dry vegetable substance is 4 Kilogram Calories.

From these basic data it may now be calculated that in one day one acre of ground along the 40th parallel of North latitude (a typical temperate zone agricultural latitude) will receive enough solar heat for the formation of 8.2 tons of dry vegetable substance, and allowing 173 days to the growing season, one acre gets enough heat to make 1,421 tons of vegetable produce.

In the perultra phases of the two main cereal agrotypes of the temperate zones, wheat and maize, a perultimate yield of the one amounts to about 13 tons of dry substance per acre, and of the other about 15 tons, and it will be seen that when these powerful agrotypes are displaying their utmost powers of life they are consuming less than one per cent of the

agricultural warmth available to them in a cool climate.

These relations offer a temptation to do a little futuristic calculating, which will do no harm if the reader accepts it as such. A few paragraphs back it was noted that the plant breeders are succeeding in lowering the nitrogen percentages of agrotypes—thus endowing them with larger potentialities of life—and that there is no telling how far this increase in the vital powers of plants might be carried. But it is certain that it cannot be carried beyond the point where all the solar heat that reaches the earth is locked up by processes of plant growth, and this point is definitely represented by 1,421 tons of dry vegetable substance per acre on the 40th parallel, with additions for lower and subtractions for higher latitudes. *If* there should be evolved new varieties of perultra agrotypes with low enough nitrogen percentages, we might at some future date find one square mile of arable land yielding in one crop cycle 909,440 tons of dry vegetable substance, containing sufficient calories (if they could all be recovered as food without loss) to give an annual minimum ration of 3,510,000 persons. At the present time it is impossible to imagine any conjunction of circumstances that would allow a greater population density than this.

However, alongside this stupendous figure representing the ultimate numbers of men on the earth there must be placed certain reservations. We forbear to picture what might be the state of the world if population should generally reach that density, and

hasten to add that it will never be attained (except perhaps locally) for a very definite physical reason. If 40 per cent of the earth's surface is arable land, and if all this land were planted to agrotypes capable of locking up all the solar heat that reaches them, the average temperature (of the whole earth) must certainly fall to about -160° F., and there is no known agrotype that can grow in such an environment. The point is that any attempt by the plant breeders to make a general capture of all the available agricultural warmth must eventually be self-defeating. But it is still conceivable that agrotypes capable of fabricating 200 or 300 tons of dry substance per acre per year (we already have such that produce 30 or more tons) might be grown on restricted areas that would be kept warm by currents of air flowing in from deserts or other areas not so intensively utilized. In that case it would not require many such areas to support an immense population.

Nevertheless, the plant breeders should be encouraged to go ahead with the work of producing per-ultra agrotypes with lower and lower nitrogen percentages, until the natural supply of heat, carbon dioxide and water show signs of playing out.

WHEN THERE IS NO MORE COAL AND OIL

We may next indulge in another calculation that has a somewhat more immediate bearing on the matter that chiefly interests us—the present abilities of nations to live at home by providing themselves with a more adequate agriculture.

The complaints of marooned groups that pine for larger places in the sun are mainly two: inability to feed an expanding or previously overexpanded population, and lack of mineral raw materials for basic industries. Chief among the useful mineral substances are coal, petroleum, natural gas, and the ores of iron, lead, copper and other indispensable metals. Metallic ores are not agricultural products, and as to them and all other inorganic materials responsibility must naturally be placed elsewhere than on the shoulders of the agrobiologist, who on the other hand may be held accountable for all organic materials or acceptable substitutes therefor.

At the present time practically every form of civilized activity is based on the use of heat and power, and except for the relatively small amount of energy derived from electricity or wood, all forms of industry, transportation and daily living involve the burning of fuel, either as coal or as a petroleum product. Both coal and petroleum are obtained from subterranean deposits which are not unlimited in extent and are being more and more depleted with the passage of time. They are bound eventually to be used up, and in view of the enormous rate of consumption the end of the supply is more or less definitely in prospect, so much so that the question is frequently raised as to possible substitutes. What shall we do when all the coal mines have yielded up their last shovelfuls of bituminous and anthracite fuel, when there is no more oil to burn in the furnace, and all the natural gas has gone?

However, current supplies are abundant, and the average citizen is inclined to regard the question as more or less academic. And so, in the main, and speaking in general terms, it is. The experts assure us that there will be no shortage of coal for at least a hundred years, and by that time most of us who now walk the earth will have passed beyond the need for ergs or mundane thermal units. But passing from the general to the particular it is noted that coal and oil production is like agricultural production—not distributed equally, which means not according to need. Some nations have superabundant supplies, others have little or none and must buy—if they can pay, which may be easy or not, depending on whether they have a sufficiency of other goods that will find export markets. A national deficiency of coal and oil is regarded as almost as great a hardship as a deficiency of food, especially as mineral fuels are held to be vital for the national defense (not to mention purposes of aggression). For this reason distant oil fields have been and still are bones of contention and diplomatic intrigue, as witness the sanguinary conflict between Paraguay and Bolivia over the Gran Chaco region. Japan is a country practically without oil resources and its rulers are openly concerned about the national safety. Can any one guess the probable direction of the next Japanese military adventure if rich oil fields are discovered just south of the Chinese wall?

The fuel question thus presents itself to us from a double angle: on the one hand what to do at some

more or less remote time when all the coal and oil deposits have become exhausted, and on the other hand the more immediate problem of substitutes in regions where commercial and political situations make procurement of mineral fuels difficult if not all but impossible, giving the nations involved another reason or excuse for weighing the hazards of military excursions.

To make short work of concretizing the matter, suppose that the United States was faced with the imminent exhaustion of its coal and oil and that there remained no choice but to find substitutes.

The dimensions of the problem will appear from the statement that in 1930 the total production of both bituminous and anthracite coals in this country was 530 million tons, having a heat equivalent of $1,425 \times 10^{13}$ British thermal units (B.t.u.). This coal was dug by 601,000 miners at the rate of about 900 tons per miner per year. The problem is to find, in some other conveniently obtainable substance, an equivalent supply of thermal units; and to restrict the discussion within definite limits it may be stipulated that no more than 601,000 workers are to be required to man the new source of supply. That is, in so far as concerns the element of human labor the only change involved is to be a shifting of 601,000 coal miners to a new occupation.

It is next in order to inquire where 601,000 men will find $1,425 \times 10^{13}$ B.t.u. elsewhere than in the bowels of the earth.

The only source worth considering will be some

department of the vegetable kingdom. Coal itself is merely the remains of plants that flourished in past ages. The processes by which heat units were stored up in coal are still in operation. All plants spend their lives in combining the water of the soil with the carbon dioxide of the air to form lignin, cellulose, and other burnable substances; the energy required by this process is supplied to the plants by the heat of the sun, and we have already shown the immensity of this energy lavished on one acre of ground even in temperate regions. When a match is applied to dry vegetable substance the solar energy which the plants have stored up in their tissues is set free again, and one B.t.u. has the same energy value whether it is derived from the oldest lump of coal or from the most recent wisp of dry grass. In the last analysis there is no real functional difference between the farmer and the coal miner; neither of the two has any other business than to produce heat units, with the sole difference that the heat units of the one are set free in furnaces and the heat units of the other are set free mostly in the bodies of animals. It happens that the miner's heat units are totally useless for dietary purposes, whereas the farmer's heat units may be recovered either in the dining room, the feed lot, or in the furnace.

The matter thus boils down to the following proposition: assuming that all the coal mines are in default, might not the 601,000 coal miners of the United States, opportunely turned farmers under expert direction and supplied with all requisites for the prac-

tice of creative agrobiolgy, proceed to continue in a new and less hazardous way their previous function as suppliers of $1,425 \times 10^{13}$ heat units to American furnaces?

From what has gone before in this book it will immediately be seen that the matter becomes one of selecting an agrotype with a sufficiently large quantity of life, in which the protein/non-protein ratio is as wide as possible, such agrotypes being most effective in the capture of solar energy per unit of land area.

As a subject for consideration, consider an agrotype with a medium quantity of life such as corn (maize), which in its perultra phase is known to yield at the limit rate of about 15 tons of dry substance in one crop cycle (counting in grain, cobs, husks, stalks, leaves) per acre. This dry vegetable substance has a thermal energy value equivalent to 10 tons of ordinary run of mine coal. The rest is a matter of simple arithmetic. To produce his annual equivalent of 900 tons of coal each of the 601,000 coal miners opportunely turned into a farmer, if he were shown how to deploy the full growth power of this agrotype, would need to cultivate somewhat less than 90 acres of land, which he could conveniently do if the work were well organized and the farms equipped with the most approved machinery and overhead irrigation. The total area thus given over to fuel production would amount to about 60 million acres, which is appreciably less than the 80 or 90 million acres that, in the hurry-scurry days of the A.A.A., it was

proposed to withdraw from cultivation for the reason that the country was producing so much vegetable substance (including corn) that the Government had to pay farmers to circumscribe their activities as tillers of the soil. When the matter actually gets vital it is hardly likely that the choice will fall on corn but rather on plants with much wider protein/non-protein ratios, such as the great reeds (*Arundinaria*) of the southern states and other plants now regarded as useless.

It remains to consider how currently produced vegetable matter will take over the present functions of coal, petroleum and their by-products. It may be granted that the new fuel will have to be handled differently than coal, but when the combustion and power experts face the situation they will doubtless convert the heat values in farm products on the spot into electricity for transmission over wires, or into gas for transportation by pipe line; both these methods are now used to transport heat units from coal.

The next question that might be asked is, how could heat units of farm vegetable matter substitute for the gasoline that is nearly universally used for propelling automobiles? There are three answers. The first is that, given an adequate supply of vegetable matter, no technical difficulty stands in the way of obtaining large quantities of carbon monoxide and hydrogen from which any substance derived from coal or petroleum may be synthesized, including gasoline, lubricants, dyes, medicines, etc. The Germans

of late have been especially active in laying the scientific foundations for such processes, not knowing how far they might have to carry their autarchy.

The second answer is that automotive vehicles can be and are being operated in quite a satisfactory manner on wood power, using an adaptation of an old, familiar device of industry, the gas generator. A gas generator is a specially constructed furnace in which carbonaceous material—sawdust, for example—is subjected to an auto-destructive distillation whereby an inflammable gas is produced; this gas, when mixed with air and exploded, generates power in exactly the same way that gasoline generates power in an automobile engine. All that is necessary is to attach one of these generators to the automobile where the gasoline tank is usually carried, charge it with enough finely chopped wood or any other kind of dry vegetable matter, and proceed on your way. Sixteen pounds of waste wood is equivalent to a gallon of good gasoline. As might be surmised, this device, as applied to automotive transportation, has made most headway in European countries where petroleum supplies are scarce and costly; it started not long ago in Finland, which has no oil but much sawdust, and in a short time has spread to other countries similarly situated: Italy, Austria, Czechoslovakia, Switzerland, Germany, France, etc. In all these countries it is beginning to displace gasoline for driving omnibuses and trucks, wood power in these countries costing less than either gasoline or Diesel power derived from imported petroleum.

The gasoline problem is capable of a third solution wherever large supplies of starch, sugars or cellulose are obtained from agrotypes with wide protein/non-protein ratios. For example, the sugar cane, which in its perultra phase yields 65,000 pounds of fermentable material in one crop cycle, could furnish, annually, 10 tons of absolute alcohol per acre, equivalent to 60 barrels or 2,520 gallons of gasoline. The domestic consumption of gasoline in the United States in 1930 was 395 million barrels. From the above data it may be figured that the equivalent of the annual gasoline requirement of this country could be supplied from an area equal to about half the small state of Maryland. Sugar cane does not grow in Maryland, but does grow in Florida and the adjacent West Indian islands. In more northerly regions the sugar beet could serve as the raw material.

However, in view of the eminent practicability of the wood "gasogene," it is unlikely that any nation deprived of petroleum would need to produce alcohol for fuel or power purposes, except under politico-economic pressure from agrarian interests.

Chapter VII

PEOPLES BEYOND THE THRESHOLD

THE FOREGOING represents about all that need be said at the moment about the boundaries of plant life and their relation to the theoretical limits of the population problem. To go into greater detail here would probably weary the general reader; as for professional economists and agronomists who may perchance feel that certain minor points have been left obscure, they are referred to the Appendix and the general body of agrobiologic literature.

The upshot of it all is there are not one but many maximum productivities of land, and consequently there are not one but many calculable limits to density of population. This is because land or soil does not of itself produce food; that is exclusively the function of living vegetable organisms and their supporting chemical and physical factors of growth. Every distinct agrotype has its own distinctive quantity of life, and thus, *in the limit*, quantity of plant life and quantity of human life are perfect correlatives. The comfort and luxury which an autonomous group of men may obtain from their arable land will depend, in the first instance, on making the right

choice of agrotypes, and secondly on establishing a skillful control over the supporting factors. When all this is done, there will be no physical or biological reason why one square mile of arable land should not support more than ten times the densest population that now exists on the face of the earth.

But, at present, it is still very far from being a matter of making one square mile support 20,000 or more persons at a bare existence level. Certainly, neither the reader nor this writer will look forward to such an existence with any degree of relish; a population that succeeded in attaining a density of 40,000 might be complimented on its agrobiologic skill, and still be entitled to commiseration for a hard fate. What interests us now is not so much that 40,000 people might frugally live from one square mile, but how luxuriantly 2,000 or less could live from that same square mile. This angle concerns us all the more because certain populations that, from our standpoint, are very far from being even half saturated, are feeling that they have reached or are reaching the end of their resources under the old agronomy, and are revolving the thoughts that such situations engender. It is our next business to emphasize the fact that the spread between a population of 2,000 and one of 40,000 is twenty-fold; between 1,000 and 40,000 it is forty-fold. With such wide margins any existing group could multiply both itself and its consumption of products of the soil many times, and still have a vast reserve to draw upon. There is still available great room everywhere within which man may

obey the ancient injunction to "multiply and replenish the earth."

An agriculture designed along agrobiologic lines to support in comfort a population of only 2,000 to the square mile will be relieved of some of the more onerous postulates that would be laid on an agriculture that had to support 40,000. On the one hand it would not be necessary to insist that the soil shall be made completely fertile, and that only perultra agrotypes of wide protein/non-protein ratios be cultivated, except as a matter of convenience and labor saving. Of course, if perultra agrotypes are available, and if it is not too much trouble to put the soil in a condition of fertility, it would be foolish not to plan for the perultimate yields that could be had for the taking, because in that case less land, labor and general expense would be needed for producing all that is wanted. The fact is that the quantities of plant life represented by the formula $318/n$ are so vast, and the densest existing populations are relatively so sparse, that the theoretical perultimate yields can be heavily discounted and a more than sufficient margin will still be left.

For instance, the theoretical perultimate yield of wheat with a nitrogen content of 1.25 per cent (whole plant) is 171 bushels of clean grain, which we have previously figured is capable of supplying 11,315 persons per square mile with a daily ration of 2,500 calories with 104 grams of protein throughout the year. But no wheat agrotype is known to have attained perultra status in field practice; the highest

rating yet found for the wheat plant on the absolute scale of growth power in open fields is a trifle over 71 per cent. However, the plant breeders have not yet finished with it; and the geneticists, who have to their credit a strain that in open field practice has yielded 122½ bushels per acre, are now speaking of a 150-bushel strain as though it were already in sight (Prof. Georges Ray). When attained, such a strain will rate 88 per cent on the scale of plant life. But looking away from all future prospects, and counting only on what is actually in hand, a wheat agrotype that rates 70 per cent and is grown in a perfertile soil is still able to provide the conventional minimum ration for 7,920 persons per square mile. Discount this 30 per cent for contingencies and enough will be left to feed 5,544 persons.

This raises before us the very practical matter of ascertaining the positions of the commoner agrotypes on the absolute scale of growth power. These are

TABLE VI.—RATINGS OF FIELD CROPS ON THE SCALE OF GROWTH POWER

<i>Kind of Crop</i>	<i>Known Yielding Power</i>	<i>Theoretical Yielding Power</i>	<i>Percentual Rating</i>
Corn (maize)	225 bu.	225 bu.	100
Wheat	122½ bu.	171 bu.	71.6
Oats	245.7 bu.	395 bu.	62.2
Barley	122.5 bu.	308 bu.	39.7
Rye	54.4 bu.	198 bu.	27.4
Potatoes	1,156 bu.	1,330 bu.	86.8
Beet sugar . . .	7.77 tons	9.8 tons	79.3

given in Table VI. This list has been printed many times, but not always with the same values; as the plant breeders go forward with their work, and as the practical agrobiologists achieve greater perfection in their art, the subultra agrotypes make closer and closer approaches to perultra status, which has been definitely achieved by corn and some others.

There are three columns of figures in Table VI. The column headed "known yielding power" states the highest verified yields that have been noted under practical field conditions. The "theoretical yielding power" is the perultimate yield calculated from the formula $318/n$ (allowance being made for offal). "Percentual rating" represents the present position of the agrotype on the absolute scale; subtracting this rating from 100 gives the margin within which the plant breeders may still further enlarge the quantity of life possessed by the agrotype.

For present purposes our interest will center on the first column. The figures in this column represent what has been done, and *ipso facto* they represent what can be done again, because the law of constancy of genotypes and the other universal principles of agrobiology are not dead-letters. In plant biology, as in all other branches of natural science, there is nothing more absolutely certain than that reproduction of the same set of circumstances is always attended by a reproduction of the same set of consequences.

Therefore, independently of all theory, and totally aside from the classification of agrotypes as perultra

or subultra, and without regard to the validity or invalidity of the formula $318/n$, the figures given in the first column of Table VI represent a *visible* and *attainable* limit to the yielding powers of seven of the principal agrotypes on which men depend for food; and *ipso facto* they set an unmistakable limit to the density of a population that would live by them alone. With these verified demonstrations of the positions of food plants on the scale of growth power it is possible to make some definite calculations of saturation densities of population.

The limit densities of population that may be calculated will depend on what combinations of these agrotypes are taken as the basis of rationing. For a sample calculation, the case may be assumed where a vegetarian population is supposed to subsist on corn, wheat, oats, rye, barley, potatoes and beet sugar, equal areas being devoted to each of these agrotypes. (The reader will understand that we are seeking the

TABLE VII.—FOOD CALORIES FROM SEVEN ACRES

	<i>Million</i>
Corn	21.7
Wheat	18.3
Oats	14.0
Rye	5.3
Barley	3.6
Potatoes	26.7
Beet sugar	28.9
	<hr/>
Total	118.5

extreme limit at which existence will be possible.) Seven acres of perfertile land planted in these agrotypes (one acre to each) will yield food calories as shown in Table VII.

With these agrotypes at their present known yielding powers, a seven-acre tract will yield a total of 118.5 million food calories; the average for one acre is 16.9 million calories. Allowing 2,500 food calories per person per day, one acre will furnish a minimum subsistence ration of grain, potatoes and sugar to 18.5 persons, or 11,800 per square mile. However, it will be noted that two subultra agrotypes, barley and rye, occupying distinctly low positions on the scale of growth power (first column Table VI), have been admitted to this list. These two minor grains may be rejected as taking up more ground than they are worth, and they would hardly be missed if the foundation ration were restricted to corn, oats, wheat, potatoes and sugar. In that case one average acre will supply 21.9 million food calories, sufficient for 24 persons per acre, or 16,360 per square mile.

Where a population is only 2,000 to the square mile the limit deduced (which is subject to expansion if more than one annual crop is produced) may be discounted in various ways. To allow for a margin of safety a discount of 30 per cent may be assigned to cover contingencies that might reduce the population-carrying capacity to 11,452 to the square mile. Then half the area could be devoted to vegetables, luxury crops and non-food crops in any proportions that would satisfy the needs or reasonable desires

of a population of 5,700. And, since the present density is supposed to be only 2,000, the population could allow itself to grow up to this figure, 5,700, which would perhaps be reached in about 75 years. By that time the geneticists will doubtless be far along with their business of enlarging the ratings of all useful agrotypes on the absolute, the caloric and the time scales, thus indefinitely keeping the limit of saturation stretched far in advance of the oncoming generations.

The calculations we have just made are based on the quantities of life known to reside in the agrotypes that mainly constitute the basis of our civilization. Our purpose in making these calculations has been to obtain a new yardstick for measuring the actual as distinct from the theoretical ability of a modern industrial nation to live by its own resources, under a régime of autarchy forced upon it by circumstances, chief among these circumstances being the nation's inability to offer goods on foreign markets in a practicable exchange for the essentials of life that itself does not produce.

What the yardstick we have calibrated can show will appear farther on, as concrete cases are taken under consideration.

GREAT BRITAIN

We will now take up the case of Great Britain, the land which produced Malthus, and where some of the circumstances foreseen by Malthus have come to pass in an aggravated form.

In Britain the population has long since increased beyond the point where it could subsist on the food produced in the home territory. The land is not merely saturated but oversaturated with people; the Malthusian threshold has been far overpassed. The degree of this oversaturation will be appreciated when it is understood that the country has about 45 million inhabitants and about 32 million acres under cultivation; this figures about 0.7 acre of cultivated land per person. Compare this with the 2.5 acres which has been assumed to be necessary for maintaining one person in reasonable comfort under the old agronomy. The comparison will become more significant when it is considered that of the 32 million acres of land reported as under cultivation, 20 million acres are in pasture or meadow (the least productive form of agriculture), leaving 12 million acres of land actually under the plow. If the coefficient of saturation is figured on the plow land alone, it turns out to be 9.77, which shows the population of Great Britain to be far more oversaturated than even the Chinese or the Hindus who devote very little agricultural land to grazing, and who furnish the classic examples of a Malthusianism that has practically run its course. Yet not only do the British manage to exist, but their gross birth rate is still in excess of their death rate.

The explanation, of course, is that the people subsist, not on home grown food as Malthus postulated, but on food brought from other countries in exchange for British goods and British services. As re-

corded in the *World Almanac*, Great Britain imports about four-fifths of the breadstuffs and fruit consumed in the country, one-half the meat, eggs and dairy produce, and one-third of the vegetables. These imports are spread over the year, so that at any one time there is only a few months' supply on hand (no wonder the British are sensitive on the subject of blockades). According to the authority quoted just above, Great Britain is the world's very best customer for agricultural products, absorbing each year approximately 20 per cent of the whole world's exports of barley, 28 per cent of the exports of oats, 32 per cent of wheat, 40 per cent of eggs, 49 per cent of cheese, 64 per cent of condensed and evaporated milk, 67 per cent of butter, bacon, ham and pork, and 97 per cent of the world's exports of mutton and lamb. This incoming volume of food is counter-balanced by an outgoing volume of manufactured goods and other values acceptable to those with whom the British have established commercial relations; they thus appear to have made themselves independent of the products of their own agriculture, and to have evaded the dire consequences which otherwise must have attended the accumulation of so many people on so little arable land.

But in the form and manner of this evasion Britain is obviously playing a game of hide-and-seek with Fate. Having shifted the base of its subsistence from its own agriculture to the products of soil controlled by others, it has hung over its head a sword of Damocles; to many of the British the threads by

which this sword is suspended may seem strong and enduring. But who can tell when these threads may be cut? Let Britain lose the colonies which furnish a large market for the products of the labor of her workmen—or, what would have the same effect—let these colonies develop their own industries to the point where they could meet their own wants; let her lose control of the seas, and let her carrying trade and a large part of her export trade pass into the hands of abler or more powerful rivals (any of these eventualities are possible, and some are on the way), and the law of population would promptly assert itself. The present condition of oversaturation would immediately revert to at least the condition of equilibrated saturation; the excess of population, in so far as it could not subsist on its accumulated capital or on international charity, would be precipitated into the grave.

So Britain feels that she must arm to insure the life of her people. The sea lanes must be kept open for the inbound transport of her daily bread, and the outbound transport of the goods that must be exchanged for it. Other nations, perhaps themselves under the pressure of desperate necessity, must not be allowed to gain positions from which they might help themselves at Britain's expense; hence the traditional policy of balance of power. The great fleet with which Britain is ringed about serves the obvious purpose of guaranteeing against a disastrous blockade in time of war (such as nearly succeeded in 1914-18), and as a clearly visible means of supporting demands

for an equitable share in world commerce. In discussions between the British and the Japanese over the division of textile exports neither side needs to express all that is being thought of. Both these nations maintain huge armaments at cruel costs, because both have outgrown the capacity of their soils to feed them; from the agricultural standpoint both are deeply involved in the latter stages of a Malthusianism from which there is no escape by traditional methods of farming, and meanwhile they must keep what they have and improve every occasion to better their admittedly insecure positions.

It is not our present business to explore all the angles of the disarmament question or to go deeply into the various currents of international affairs that might lead Britain into another war. We have here mainly to consider whether the British have just reason to despair of their own source of supply, and to raise the question: Must Britain really depend on food from overseas? If not, the prospect of an eventual blockade will be robbed of much of its terror, and one reason for the maintenance of a fleet larger than that of any other nation will be done away.

Our proposition will be accomplished if we point out, objectively and from the technical standpoint, how the present food situation in Britain might be altered.

We approach this discussion armed with three inexpugnable facts:

(1) That the climate and soil of Great Britain, especially that of England and Wales, are well adapted

for growing the principal crops, such as wheat, barley, oats, potatoes, sugar beets, flax, vegetables, etc.

(2) That under the simple, known conditions of creative agrobiolgy the yields of crops are or can be made virtually independent of ordinary crop hazards, so that when a powerful agrotype is supplied in a proper manner with the necessary plant food and moisture a maximum crop is the infallible result.

(3) That there are now known to exist strains or varieties of crop plants which in genotypic yielding power on English soil have demonstrably progressed far toward the theoretical perultimate limit, quite independently of whether the theory itself is valid or not.

Other materials for the discussion we find in the facts previously cited, namely, that the present population of Great Britain is about 45 million; the present area of land under the plow is about 12 million acres, and another 20 million acres are in pasture.

If all the British plow land were made perfertile and planted with completely edible perultra agrotypes having protein/non-protein ratios of 1 : 11.5, so that one acre would furnish to 51 persons the minimum subsistence ration of 2,500 food calories (see Chapter IV) with 50 grams of protein, it would be possible to keep alive 612 million Britons at the lowest admissible level of comfort; 45 is 7.35 per cent of 612, so that the present population of Great Britain is only 7.35 per cent saturated on the basis we use. There is still, theoretically, room for an additional 567 million people in the country, if none

are allowed more than the lowest minimum of food. This scarcely conceivable figure is introduced merely to indicate the wide margin within which the problem might be solved.

As a more practical approach to the question we may turn to Table VII, where are given the food values per acre known to be producible from the common field agrotypes. Corn (maize) is not yet grown to any extent in Britain, but the four well known agrotypes wheat, oats, the potato, and the sugar beet are thoroughly at home in that country. One acre each of these crops, if caused to produce at their maximum rates, will yield an average of 21.9 million food calories in edible form, from which it may be calculated that the 12 million acres of British plow land will furnish 289 million persons with our minimum annual ration. On this new basis the population of Britain is still only 15.5 per cent saturated, which indicates that there may be room in Britain for an additional 244 million.

However, there are actually no more than 45 million people in the country—less than a sixth of that number of people (289 million) who could be fed at a level with which countless myriads of Orientals have to be satisfied. There is thus a wide margin for discount.

As a first discount suppose that instead of expecting British farmers to attain the known maximum yields of these four crops, the required average yield be set at 60 per cent of the known possibility. They would then be producing $73\frac{1}{2}$ bushels of wheat,

147 bushels of oats, 693 bushels of potatoes and 4.6 tons of sugar per acre. British soil and climate are known to be capable of even higher yields, and in agrobiolgy what has been done once can be done again. Under such a standard of performance the basic ration will be produced on 3.16 million acres. Let even this be discounted 50 per cent—that is, impose on British agriculture the requirement of producing only 30 per cent of what is known to be possible. This would merely raise the acreage to be put into the standard crops to 6.32 million acres, leaving 5.68 million acres for the intensive cultivation of luxury crops. Or, keeping the yield at 60 per cent, suppose the daily ration be increased to 4,500 calories with 100 grams of protein (surely enough for the most vigorous people); there would then be needed 5.68 million acres for the standard crops, leaving 6.32 million acres for the application of advanced agrobiologic methods in the culture of luxury crops.

The foregoing considerations land us on the conclusion that the British agricultural establishment, now reduced to a remnant of its former state by a ruthless policy of favoritism to industry—and even regarding only the land still under the plow—is more than sufficient to render the island immune from starvation by the tightest of blockades, *provided*, that this land is worked at a level of agrobiological efficiency that need not exceed about 60 per cent of the known possibility.

It is not necessary to rest the case at the point to

which we have just brought it. So far, we have considered merely the conditions to be fulfilled in order that Britons might be kept alive on a rather narrow diet of grain, potatoes and sugar, and there may be Britons who will conclude that existence on such terms is hardly worthwhile. The people are largely beef and mutton eaters, and they will want milk, fruit, and vegetables; it is not merely a question of living, but also of living well.

Considering the known resources of agrobiologic science there is no reason at all why Britons should not live exceedingly well on what, from the standpoints of the old agronomy, is an excessively diminutive area.

Our calculations have shown that a very liberal foundation ration can be procured from 5.68 million acres of British soil, leaving 6.32 million acres for the production of dietary accessories. The 12 million acres we have used as the basis of this discussion is land that the British farmers are still actually turning over with the plow. In the long process of shrinkage to which the British agricultural establishment has been subjected since the repeal of the Corn Laws, the unprotected British farmers have gradually been compelled to throw more and more good farm land out of cultivation into pasturage, a use that involves less chance of financial loss even though the gross returns are much smaller. This shrinking process is still going on, and while there are signs of a belated recognition of the folly of allowing it to continue, there is still a formidable remnant of Cobdenism that

would be satisfied with the total extinction of the British plowman, and to have the country's dependence on foreign-grown food made complete. However, that is no outsider's business; from our position of detachment we have only to consider how the British, if they were so disposed, might insure their security in view of contingencies likely to arise at any time.

There are now 20 million acres of pasturage in Britain. Ordinarily, a pasture is a fenced piece of ground on which grass or other herbage is allowed to grow spontaneously, and on which cattle are turned loose to graze. Pasturage is the simplest form of agriculture, involving no more labor than turning out the stock in the morning and bringing them in at night; it is also the least productive, because as ordinarily carried on the grass is left to grow of itself on what plant food is afforded by the slow natural processes of soil decay. It is only recently that the agronomists have awakened to the fact that the laws of plant life apply to agrotypes growing in the undisturbed soil of pastures as well as to agrotypes growing in soil that has been loosened by the plow. It has been observed that if the soil of a pasture has been made richer by strewing fertilizer on it, the grass will make a better growth and the pasture will carry more stock. Perhaps we should not call such a simple observation a discovery; the real discovery lies in the fact to which we have previously made allusion, namely, that when young plants start to grow they make it their first business to accumulate as

much as possible of the plant food within reach for use in the later stages of growth; when such immature plants are harvested they are far richer in protein and other nutrients than they will be percentually when normal growth has been finished. Immediately after being thus cut, the plants start a new growth cycle, and if well fertilized and watered a rapid succession of crops of valuable fodder is obtained that in the aggregate is vastly greater than if the pasture is left to the traditional *laissez faire*.

How this bears on the problem of maintaining the British food supply, not only in security, but also in the equivalent of substantial luxury on what has been regarded as a totally inadequate extent of cultivated land, may now be brought under consideration. Under the leadership of Professor Woodman of the Cambridge University School of Agriculture the British agronomists have very convincingly demonstrated the possibilities that lie in this direction, and it is to be hoped that their work will eventually make its due impression on the British public.

In brief, when an acre of British meadow is kept well fertilized and watered and mowed every four or five weeks during the growing season it yields up to 5½ tons of tender hay.

The fact that an acre of ground yields 5½ tons of hay may sound too utterly commonplace to deserve mention in a serious book. But this is no ordinary hay, such as ordinary farmers have been producing for countless generations. It is as rich in food values as any grain, and quite as digestible by all kinds of

stock, including pigs and chickens. For stock feeding purposes those $5\frac{1}{2}$ tons of hay are the full nutritive equivalent of 180 bushels of English wheat or 196 bushels of Argentine or American corn. One acre of such hay land will maintain one cow yielding six U. S. gallons of milk a day throughout the year. By keeping 2 million acres (one-tenth) of their 20 million acres of pasture under the Woodman régime the British could give every one of their 45 million people a full quart of milk every day. An additional 8 million acres under the same régime would daily supply every Briton with half a pound of flesh food—beef, mutton, pork, poultry—along with leather and wool as by-products for shoes and woollen clothing.

To sum up, we conclude that by subjecting half their plow land and half their pasture land to thoroughgoing exploitation on agrobiologic principles the British may well supply themselves with all the bread, oatmeal, potatoes, sugar, beef, milk, eggs, pork, mutton and poultry they can possibly consume.

We mean to say that, even at a standard of living higher than the American, the 32 million acres of British soil now under cultivation, which are 350 per cent oversaturated by data of the old agronomy (East), are only 50 per cent saturated when appraised by the new agrobiology. This means not only that the country can make itself completely independent of all foreign food (aside from exotic non-essentials), but also that so far as the means of sustaining life are concerned the British might well throw birth

control to the winds and allow their present population to more than double without curtailing a standard of living much above the average they are now enjoying.

Thus agrobiology shows that Britain need not rest under the continuing threat of starvation by blockade. There may be other reasons—real or apparent—for maintaining a vast navy at enormous expense—an agrobiologist has nothing to do with that—but necessity for insuring the food supply is one reason that can be done away. Britain cannot be starved when Britons have put their agriculture in order and have squared their treatment of the land with the realities of science. They may always feel the need of some sort of a war fleet, but so far as anxiety over their food is concerned it is within their choice to reduce their present war flotilla to proportions such that it will not be interpreted as a standing threat against other nations that would gladly exchange the burdens of militarism for peace with the abundance that agrobiology promises.

However, this is mostly a pragmatic world and great questions of public policy, if they are kept free from emotionalism, are generally settled on a basis of relative costs. The cost of insuring Britain's food supply by means of a great navy is, as all the British know, a painful matter of record in the annual budget. In round figures the British spend £60,000,000 a year on their war fleet. At current rates of exchange this is equivalent to about \$300,000,000. Suppose that this annual expenditure for

war purposes is cut in half; how far would the \$150,000,000 thus saved go toward insuring the British food supply by non-military means?

It is susceptible of demonstration, as a matter of agricultural engineering, that the capital cost of draining, irrigating, neutralizing and otherwise preparing an acre of British soil for all the purposes of creative agrobiolgy, including an adequate stock of the chemical and biological elements of soil fertility, need not exceed \$200 per acre, and we are much disposed to regard this figure as extravagantly high. If we divide 150,000,000 by 200, we obtain the quotient 750,000, which is the number of acres that could be put, every year, into a state of productivity that is agrobiologically as great as need be, using the annual savings resulting from a 50 per cent reduction in the cost of maintaining the great British war fleet. At that rate only five years would be needed for agrobiologically equipping 3.75 million acres, which is about the area we postulate as necessary and sufficient to insure the feeding of all the people on a subsistence level. Continue the process another five years, and the comfort level is passed, and in a few more years the luxury level will be approached.

The rate at which British agriculture is thus transformed is a matter of detail and is something to be determined by the British themselves. The proportion of the national wealth that is annually diverted from military purposes for the purpose of creating the new national security and plenty will perhaps largely depend on the readiness of Britain's potential

enemies to divert corresponding proportions of their resources to the same sane object. Here is a new element of bargaining that might well be introduced into future disarmament conferences: coupling agreements to reduce military expenditures with agreements to make equivalent expenditures in directions that would relieve the pressure of population that makes military expenditures necessary—what would be a better guarantee of good faith all around?

However, at the moment these details stand beyond our proposition, which is merely to show that, from the scientific and technical standpoints, the matter of relieving pressure of population on the supply of agricultural raw materials appears feasible enough. In another chapter we will have something to say about organizational set-ups for materializing the new condition of national and international security, peace, and plenty. For the present we limit ourselves to the suggestion that if the British are equal to the practical business of subjecting at most half of their cultivated land to the regimen of creative agrobiolgy, the population might all be comfortably nourished on home-grown food. If, on the other hand, the British cannot or will not avail themselves of the means for rectifying their position held out to them by science and practice, they will continue, as now, subject to the perils of a highly oversaturated population in a politically and economically unstable and dangerous world.

ITALY

The precarious position of the British in this unstable world mostly concerns themselves alone. Britain's career of conquest and expansion is about over. The British are now mostly concerned to keep what they have. What they now have may not be entirely satisfactory, and some of it may be slipping away, but there are few audible mutterings of a will to transfer British woes to other breasts. As we survey this unquiet world we notice other nations that seem to be less forbearing, less content with their present places in the sun, more ready, apparently, to fill their comparatively bare national cupboards at the point of the more familiar sword rather than with the plow, the full rational use of which agrobiologists has yet to teach them. In this connection we may observe the ferment that has been working in Italy.

As is generally known, Italy is predominately an agricultural country, with a population (now about 42 million) which is still showing a gross increase, although the net reproduction rate seems to be tending downward. It may be that Italy's population may become stationary at not much above the present figure, but even so, from a sociologist's point of view, there are already too many people in the country, the result of past fecundity; a dangerous pressure of population on the soil has already accumulated. According to our Table II the relative coefficient of saturation is 1.96, which is practically double the base on which this Table has been calculated, and

when figured on the actual plow land the coefficient is 3.80. The country is ill supplied with mineral wealth, especially as regards coal and oil, and it thus lacks a necessary basis for sustaining a large industrial population who might gain their livings from international trade, so far as there is any. This being the case the new generations of Italians are confronted with the alternatives of finding places on the already crowded soil or emigrating to other regions offering better chances. Either of these choices is almost a practical impossibility. Already the soil barely feeds the teeming population. Many foreign countries have raised barriers against the influx of Italian immigrants, and the financial cost of emigrating to the few remaining distant territories is high.

Only a few years ago the population was increasing at a rate alarming alike to Italian public men and to those of neighboring countries. In several of his pronouncements Mussolini, the Fascist chief, has compared Italy to a steam boiler under which the fires are becoming hotter and hotter, and the accumulating steam is showing a constantly mounting pressure; this steam, he said, must be blown off or an explosion must surely result. Mussolini himself has summed up the situation in the following quotation:

“According as our population increases there are three outlets: to condemn ourselves to voluntary sterility—and Italians are too intelligent for that; to wage war; or to place our surplus population elsewhere.”

In other words, Italy is confronted with a choice of

three options. The first Mussolini would have the Italians decisely reject, and the last is proving to be impracticable on account of the unwillingness of peoples of other desirable regions to receive large numbers of foreign newcomers. There remains the middle one, which has been interpreted as an enlargement of Italian national resources by the forcible seizure of nearby territory. Naturally enough, the implications of such a situation have a decided interest for all of Italy's near or even remote neighbors, and for all who view with apprehension the outbreak of new world conflicts.

Although the recent decline in the rate of increase of Italy's population seems to have made the threatened explosion somewhat less imminent, the situation is still far from satisfactory. There may be less present reason for being concerned about future overcrowding, but there is plenty of reason for being concerned about the overcrowding that has already come about.

It might be supposed that the evident decrease in the birth rate would be hailed by the Italians with something like a feeling of relief. But in so far as important Italian opinion is represented by Mussolini (whose opinions are of chief importance) the decline in the number of births is to be regarded as a national misfortune because of the weakening effect on the country's future military strength. For this reason Mussolini has strongly opposed birth control on the ground of public policy; Fascismo, abetted by the Church, has turned heavy batteries of propa-

ganda in favor of more rather than fewer births, and its propaganda is reënforced with practical social-economic measures tending to re-feminize the women by turning them back from business and industry into the home. Obviously, Fascismo wishes to build up man power for the second option. Such appears to be the intention of Mussolini's astonishing measures for the universal military training of Italian youth, beginning with boys at the tender age of eight.

But a pragmatic pacifism and all friends of international peace may well draw the attention of Fascismo to a fourth option. Those who mount the chariots of Mars commit themselves to a journey the end of which no man can clearly foresee. By war the Italians might gain for themselves more elbow room, but the adventure would certainly be under the risks of a desperate gamble with ruin and death, and in any event must involve a great cost of blood and treasure. On the other hand, let us see what an appeal to creative agrobiology might accomplish.

The area of Italy, in round figures, is about 76 million acres, of which 53.3 million acres are under cultivation of some sort. Of these 53.3 million acres there are about 27.6 million acres (more than twice the area of plow ground in Great Britain) devoted to the principal food crops: wheat, maize, rice, sugar beets, beans and potatoes; the average rainfall, taking the country as a whole, is above 36 inches. We have just calculated that Great Britain, with 45 million inhabitants, might, by resorting on a large scale to creative agrobiology, be able to provide her people

with more than enough food from 12 million acres. We shall therefore have difficulty in convincing ourselves that the Italians, with more than twice as much plow land and with not quite so many inhabitants, are under any real necessity of sallying forth, like the Helvetii of Cæsar's time, to occupy neighboring lands.

Whatever may be Italy's apparent need for expansion on account of the ineffectiveness of her ordinary agriculture, we may declare that, in view of the known resources of creative agrobiolgy, she is very far from any real danger of inability to feed and clothe her people abundantly from the products of her own soil. She has mountains from which to draw a vast amount of irrigation water to supplement the rain that falls on her fields, and there is absolutely no physical, chemical or biological reason why the Italian farmers should not attain an agrobiologic efficiency of at least 60 per cent of the known possibilities inherent in the major food crops on at least half the ground ($13\frac{1}{2}$ million acres) they are now cultivating, and thereby produce more food and agricultural raw materials than the nation would need to consume. And if they should go further and subject all their plow ground to the full régime of creative agrobiolgy they could provide a more than sufficient living for more than twice their present population.

If, therefore, Italy should appeal to arms to enlarge the ability of her people to live, it cannot be admitted that it is because they have even approached the be-

ginning of the end of the capacity of their land to sustain them.

It is by this angle that a real, constructive peace movement, that seeks not only to talk down war but to talk something into its place, should endeavor to make itself felt.

Taking things as they are, the situation in Italy unquestionably needs improvement, both for the sake of the Italians themselves and the non-Italians that are likely to be involved in the threatened explosion. The issue is clear-cut, and the problem is to be solved in one of two ways: by an appeal (under some convenient pretext) to the chances of war; or by an appeal to the resources of creative agrobiology. Which, we may ask, is likely to be the more effective and the less expensive? Before answering this question we may do a little calculating.

As a result of the Great War, which Italy entered for the express purpose of enlarging her boundaries, the Italians gained 9,084 square miles of territory formerly under the control of hostile powers, and saddled themselves with a total war expense of 27 billion dollars at par of exchange. It is true that this enormous outlay has been greatly reduced by repudiation by way of inflation and a process of scaling down because of inability to pay, but *somebody* has paid or will pay it, as many people in the United States and elsewhere have good reason to know. Besides the outlay in treasure the Italians had 1,597,000 killed and wounded in that great conflict, or 175 casualties for each square mile of territory gained,

but figuring only on the basis of money cost it may be computed that the new land acquired cost \$4,276 per acre. Surely this is a high price for even a rich nation to pay for a mountainous terrain that, if it were all capable of development for ordinary agriculture, could support a very small fraction of Italy's present population.

Can Italy hope to acquire more and better land by a war that would cost less? She might, but the risks would be enormous. On the other hand, what might be the relative cost of putting half of Italy's plow land into a condition where it could support more than the present population on a higher level of comfort?

Aside from an agrobiologically well-proportioned supply of fertilizer, the chief need of Italian soil, as it is of all soil where ordinary agriculture is practiced, is an adequate and well-regulated supply of moisture in order that the crops may effectively use the plant food furnished to them. If we allow the rather liberal estimate of \$200 an acre as the cost of providing works for utilizing the existing water resources that are now being wasted, 13.5 million acres could be put on a basis for practicing creative agrobiology at a cost of 2.7 billion dollars, or exactly a tenth of the wealth that Italy sunk in the acquisition of 6.13 million acres of land which, whatever value it might have on other grounds, is nearly negligible as a means of relieving the pressure of Italy's population.

What would the Italians have for this 2.7 billion

dollars invested in new means of existence? Without repeating calculations that have been exemplified in preceding chapters of this book, it may be stated that they will have more than doubled the productive capacity of half their plow ground, which would be equivalent to annexing more than 13.5 million acres of clean farm land now in the possession of others; and this vast expansion of their agricultural resources and wider life for their people would be achieved at a cost of \$200 an acre, which may be compared with the \$4,276 an acre which they expended for 6.13 million acres of mostly useless land acquired by war. Hope springs eternal in the human breast, and there may be Italians who hope that the next war will be less expensive and more profitable than the last one. It might be admitted that war is justifiable for certain reasons, but judged by its results in this case it is surely a highly ineffective means of enlarging one white nation's food resources at the expense of another white nation.

However, if Fascismo, as mirrored in the activities of Mussolini, excites apprehension by its scorn of birth control, its universal military training of male youth down to boys eight years old, and its continual harping on the necessity and unavailability of war—this same Fascismo, when discerningly examined, is found to be actually far on the road which we ourselves would counsel Italy to take. While Mussolini is whipping up the war spirit with his one hand, with the other hand he is even more busily engaged in putting his country into a posture such that it

may easily become totally beside the point to even think of coveting a single neighboring acre. Whether intentionally or not, in Italy there is being prepared the groundwork for a realization of the agrobiologic ideal of overflowing abundance. It may be assumed that most readers who make it a point to keep in touch with what is going on in the wide world have had their attention directed to the spectacular projects of land reclamation and land improvement now under way in Italy; the Pontine marshes, that for ages have defied the labors of ancient and modern Romans, have at length yielded to the compelling will of Il Duce. Vast tracts of Italian soil that suffered from an excess of water have been drained and put under the plow; other vast tracts that suffer from a lack of water are to be brought under irrigation. Thus the creation of a physical basis essential for a creative agrobiology is being pushed forward.

No less spectacular to the instructed onlooker, but perhaps less well understood by the generality of persons interested in the promotion of international peace through nullification of causes that predispose nations to go to war, are the preparations being made on the biological, social-economic and psychological essentials of national well being. Fascismo is engaged in reorienting the Italian body politic along lines that, in theory at least, will bring about a higher order of social-economic security for all. But however *that* may be, Fascismo is obtaining results along the line that interests us; it is actually doing something towards developing what we have previously desig-

nated as the fourth option for the solution of Italy's population problem. Both in its conception and its results Mussolini's achievement of his *vittoria del grano* will alone entitle him to the character and reputation as a leader of men in constructive social-economic action. He found Italy short of wheat; he called on Italy's farmers to produce greater yields of wheat per unit of plow land, and they did; in not a few instances they have demonstrated that even with the subultra wheat agrotypes now in use the yield can be pushed far toward that seemingly fabulous limit of 171 bushels an acre set by the formula $318/n$. Notice these record yields which were hung up in five provinces in 1934: 98 bushels in Brescia, 102 in Aosta, 106 in Cremona, 107 in Vercelli-Turin, 123 in Parma; these yields reach 55 and 71 per cent of the theoretical possibility. *When enough Italian farmers have been stimulated by precept and example to achieve no more than 50 per cent of the theoretical efficiency, the wheat they now produce on 12.5 million acres will be raised on 3.5 million.*

The Italian agrobiologists and geneticists in the service of practical agriculture have also been busy. According to reports that have recently come out of the Institute of Agricultural Chemistry at Rome, Professor Thomasi, by making a thoroughgoing application of agrobiologic principles to some new strains of wheat, has produced 11,000 pounds of wheat to the acre, which is practically identical with the theoretical perultimate yield of 171 bushels. Wheat has thus definitely been added to the number

of plant types on which the geneticists have succeeded in conferring the maximum quantity of life. It only remains to transfer Professor Thomasi's wheat to agrobiologically well-furnished land, and the Italians may have their present supply of bread, spaghetti and macaroni from a sixth or less of their soil now given over to wheat growing, and they will have it for a greatly reduced expense for labor and material.

Other Italian agrobiologists have been busy with other great staples. Professor Novelli, Italy's rice expert, is credited with the production of strains of the rice plant that attain maxima of 8,000 pounds per acre. A square mile of such rice means the yearly equivalent of a standard ration of 3,600 food calories daily for 6,400 persons; this exceeds by far the present ratio of population to arable land in any known country of the earth. If bad should go to worst and the 42 million Italians should be driven, like the Chinese and the Japanese, to subsist largely on rice they could, using the means now held out to them by their rice agrobiologists, achieve a more than Oriental comfort from a fourth or less of their land now under the plow.

Thus Fascismo, while it is paying what seems to be an exaggerated devotion to Mars, is vastly encouraging its agrobiologists and its farmers in the patronage of Ceres, and the gentle goddess may well end the competition by proving the entire superfluity of the war god as a purveyor of national life, peace, and social-economic security.

The friends of international peace and the haters

of war, especially the haters of unnecessary wars—leaving aside the question as to whether any war is ever necessary—will of course range themselves on the side of Ceres. When the Italian Mars begins to rattle his saber in earnest his pretexts will be subjected to critical examination; and in so far as they rest on allegations of pressure of population on the soil, or denial of a place in the sun, they will be disallowed by the candid judgment of an enlightened world opinion. Since those things that make a people rich in all the essentials of a secure and comfortable existence may be won by the industrious and intelligent use of nearly inexhaustible natural forces, those who precipitate a new holocaust of doubtful issue under a claim of national need commit both a crime against humanity and an offense against common sense.

In other words, a pragmatic pacifism may agree with Mussolini that the first and third of his options are both impracticable and undesirable, but there still remains ample justification for condemnation of the second option, which is to wage war. Sane counsel may well make a direct appeal from Mussolini the swashbuckler to Mussolini the constructive social genius. Let Fascismo but keep its hand on the plow it has so ably seized, and in no long time Italy will have ample capacity to feed not merely 42 million but more than 100 million inhabitants. Let Mussolini proceed with the application of his principle of "integral action." Let the *vittoria del grano* be followed up by a *battaglia del cotone, della lana, del granturco*, etc., etc., and let the cost of more battleships and the

expense of arming more battalions be bestowed on bringing life-giving water and fertilizer to more of Italy's parched and hungry fields. Give the agrobiologists full rein, and they will win for Italy more comfort than a dozen wars.

This matter of giving the agrobiologists full rein should be much less difficult under Fascismo than under the economic liberalism that still prevails in such a country as England, for example. It is not the intention here to debate the theoretical merits of these two systems of political science, but merely to point out what Fascismo will be in a position to do if and when the corporative structure of Italian national life has been completed on the foundations now broadly marked out. Like all other major branches of Italian industry agriculture has been "integrated" and made capable of action as a unit, with a central body recruited from its own ranks to coordinate and guide its activity in directions that best appear to coincide with the broad national interest. In other words, Fascismo has fashioned (at least on paper) an instrument to its hand whereby a program of abundance can be initiated and controlled without disturbing the general economic harmony, because the intention is that all units of the industrial body politic shall mesh together. The Fascist chiefs have only to will that every Italian shall have his standard of living doubled, and it then remains only to materialize their planned social-economic machinery for effectuating the purpose.

Thus there exists neither in science nor in domestic

politics any reason why the talked-of Italian "explosion" should occur.

Fascism will more than justify itself in the eyes of pacifists if it uses the social-economic apparatus it has started to create to materialize for itself that new era of peace with plenty to which science and common-sense are beckoning a war-afflicted world; it could give no more convincing demonstration of the social value of a totalitarian State.

However, the issue is still in suspense; the new Italian dispensation has not yet become an accomplished fact, and it is not for us to say that it ever will. Neither do we say that it ever should; there are those who disbelieve in the principles of Fascismo generally, and particularly as exhibited in Italy under Mussolini, and there are even some who have no confidence in his statistics. All that concerns us here is the fact that Fascismo has set about the creation of a machinery that, however offensive in many respects it may be to non-Fascists, is at least potentially capable of solving Italy's problem of agricultural materials. It is the solution of this problem that mainly concerns us, and not particularly the method by which it is solved. As a matter of personal preference, this writer leans toward some other methods that are coming into successful use in various parts of the earth (no reference to Russia is intended); to set forth these better methods would require another book.



GERMANY

In the preceding discussion of the Italian situation we had before us the case of a country wherein past operation of the Malthusian principle has resulted in the accumulation of sufficient pressure on the soil to raise expectations of an "explosion," which normally will take the form of seizure or attempted seizure of means of living now in possession of peoples unable to defend them. The danger of such an irruption by the Italian Mars is not obviated by the fact that Italy's population is not now increasing so fast as it was some years ago; Italy has already crossed far over the Malthusian threshold, and the weight of past increase presses heavily on the land. However, there is some small hope that necessity for the anticipated explosion may be averted; Fascismo has taken at least a few of the initial steps that, if sapiently followed up, will lead the Italians through bloodless paths to a fabulous plenty.

When we turn to Germany it is to observe the ghastly remains of an explosion that was not averted.

Viewed in retrospect the politico-economic history of modern Germany affords a perfect example of the workings of the Malthusian principle in so far as it is pertinent to the thesis of this book.

When the Deutsches Reich was founded some sixty-five years ago the population was being substantially fed from products of the home soil. Following upon the achievement of political and economic unity came an expansion of German manufacturing and trade.

The outside world was still mostly in a backward state industrially, and there was a wide foreign market for the products of German technology. Those were the days when there was little thought or evidence of birth control; the population of Germany, as in other parts of the Occident, was increasing at the rate of more than one per cent a year; but there was not a corresponding increase in the means of food production. The natural result was that the relative coefficient of saturation with population began to increase and eventually it exceeded unity (it is now about 2.25), but the fact at first attracted little or no attention; the mills and the shops were absorbing the annual increase of workers, and importation of needed food and raw materials could be financed from trade balances that were more than adequate.

At about the beginning of the present century the leading men of Germany began to realize that the country had crossed the Malthusian threshold, and that the undiminishing birth rate of the Germans could but carry them on toward social strangulation. Germany agronomy had clearly become bankrupt, in the sense that it could not or would not meet all the ordinary demands made upon it. The disproportion between the industrial population and the domestic agricultural production was too wide to be overlooked and was steadily becoming wider; the food deficit had, in fact, become permanent. However, the native food and raw material deficit could be ignored so long as the export trade held out to supply work and foreign bread to the workers that swarmed in the

industrial centers. But there were signs that the foreign trade might not hold out. Industrialization of backward regions was going on apace, portending the loss of markets that thenceforth would be supplied by local producers. Nor was Germany's hold on the remaining markets any too secure; competition from other highly industrialized nations was becoming more intense.

Under such circumstances the von Tirpitzes and the von Bernhardis and other exponents of German imperialism began insistently to advise the Kaiser that Germany was now entering upon the same road down which Great Britain had already gone a long way, and was facing the same increasing social-economic dependence on foreign markets to take manufactured goods in exchange for agricultural products, with a notable difference between the positions of Great Britain and Germany. The British are firmly placed astride the world; they possess immense colonies and dependencies, and for two hundred years have been established as the world's leading manufacturers, traders and financiers; they own most of the world's shipping, and from the naval standpoint are undisputed masters of the seas. On the other hand Germany is a late comer in the colonizing field; what the British have not already seized in Asia and Africa is in possession of the French, the Belgians or the Dutch, and the Monroe doctrine stands in the way of obtaining a German foothold in the Americas. The few colonial scraps that Germany has been able to pick up are too meager to give much of an outlet for

German goods or to furnish adequate supplies of raw materials, and ownership of such colonies as she has now is merely on sufferance so long as her potential enemies command the seas and are able to take possession of them whenever they find it necessary or convenient to do so, after the manner of the Italian seizure of Tripoli. It is therefore imperative that Germany acquire such a strength on the seas that no one may interfere with her colonial empire or prevent her from enlarging it; she must build a navy equal to that of her most powerful rival. As an additional guarantee of her economic and political safety Germany must develop and maintain land forces strong enough not only to secure her borders but also to enforce her will when armed conflicts are to be fought out and treaties of peace come to be written: the mailed fist is no uncertain factor in the framing of commercial agreements and in the delimiting of spheres of influence; even naval disasters may be more than repaired and the fate of colonies and dependencies settled by a smashing victory on continental battlefields. In any case, the state of world economics and world politics has come to such a pass that Germany cannot long delay insuring the future of her crowded population, or avoid resorting to force to win and keep a larger place in the economic sun; her own needs and the needs and power of her rivals are growing and the inevitable conflict may well be precipitated at the first favorable opportunity, before the balance of power becomes too far displaced. From now on the

watchword for Germany can only be: *Weltmacht oder Untergang!*

World power or downfall! Such is the sinister option that confronts a hemmed-in population when it has been ushered across the threshold of Malthusianism by its too great multiplication on the one hand, and the bankruptcy of its agronomic science on the other hand. It is an option that cannot fail to arise sooner or later, whenever, for the vitals of its existence, a nation ceases to depend mainly on the resources under its control, and comes to place its trust in means controlled by or exposed to the domination of others. A social-economic structure built on an unstable foundation of foreign trade is subject to collapse under the pressure of foreign entities that also have to exist, and are perhaps themselves in the same perilous situation. Once having passed beyond the solid ground of agricultural self-sufficiency in reckless pursuit of alien will-o'-the-wisps, there is little or no chance for retreat; by arresting its birth rate the nation might avoid increasing its risk, but the excess of population it has already accumulated hangs like a millstone about its neck; it has acquired a liability that cannot be shaken off. Since there is no going back, nothing remains but to fortify the existing situation; the nation's foreign trade now having become of vital importance, it must be defended by all means; the alternative is an exchange of national prosperity for a grueling national poverty.

It is not our business to analyze all the factors

that combined to precipitate the Great War, or to assume responsibility for imputing "war guilt" to the Germans; that question may be left to impartial history. But what the chief parties stood to gain or lose is fairly obvious. If Germany had succeeded in crushing France there is little doubt that she would have proceeded with the Germanization of the French colonial empire. The demotion of Great Britain from her commanding position on the seas would have subjected the British Empire to a more or less thorough curtailment, and British trade to a degree of destruction limited only by the forbearance of the new masters. New regions would have been opened by the triumphant German navy to mass colonization by the surplus German population. Germany's sources of food and raw materials, and the markets for her manufactured goods, would not only be enlarged but their perpetuity would be insured. On the other hand, in proportion as Germany's position was bettered, that of her rivals, and particularly that of Great Britain, would be deteriorated; the British, with a population even more highly saturated than that of Germany, cooped up in their narrow island, thrust out of their preferred positions in their largest markets and their communications severed, could but experience the full effect of a Malthusianism even more severe than that which the Germans were seeking to avoid.

Such are the stakes for which great peoples send millions of their men to death, and count the sacrifice not in vain if the national heritage is expanded

or preserved. There are perhaps not many Britons alive to-day who do not regard preservation of the British Empire, the continued security of British communications and the safety of the British food supply as worth all they have cost, or who would not be ready to fight again if the same challenge were offered. On the other side, if the result had been different the surviving Germans would perhaps regard their sacrifice of two million dead soldiers as a not excessive price to pay for the coveted "place in the sun," with unlimited room for expansion, and an unimpeded development of what the pre-war Germans regarded as their national destiny.

And yet there are academic pacifists who imagine that prattle about international understanding and good will might cause such colossal genii to shrink into nothingness! Good will and understanding are certainly necessary if nations ever come sanely to organize peace. But they must first have something very tangible on which good will and understanding may operate, and that something must be in the nature of an alternative and clearly visible means of obtaining those very things for the possession of which great peoples do not shrink from going through the Valleys of Death. A pacificism that is unable to formulate such a program is not merely futile; it is fatuous.

Whether the Germans did or did not consciously accept the Austrian *démarche* against Serbia as the pretext they wanted to make their bid for what they were continually describing as their rightful place in

the sun, the desperate wager was lost. If they entered the war not only to insure their present means of life but also to enlarge them, it must have been with a realization that failure to win the war would mean not only failure to step into a larger heritage but would also involve the loss of much if not all they had already acquired; the rapine they intended to practice on Great Britain, France, and what other victims might fall before them would be practiced on themselves. And so it came to pass; the German explosion aborted. Instead of *Weltmacht*, the Fates decreed *Untergang*. The German colonies one and all passed into other ownership, perhaps never to return, and the Fatherland itself was mutilated. Thus was the German nation driven back upon itself to accommodate, as best it might, its overgrown population to the inadequate German soil.

If ever a nation needs a competent agriculture it is during a time of war, when outside supplies are shut off; and it was during the Great War that the bankruptcy of German agronomy plainly showed itself. The Allied blockade limited the Germans to what food they could produce at home or seize in the territories they had overrun; even so, there is eloquent—not to say vociferous—German testimony to the effectiveness of the Allied "*Hungerblockade*," and, if the figures gathered by the London *Economist* are to be accepted, some 800,000 surplus Germans died of starvation. So far as these unfortunates are concerned, Malthusianism proved itself capable of reaching and passing that 100 per cent end-point

which the statisticians have dismissed as an impossibility. With the cessation of hostilities the Germans again obtained access to outside food supplies, for which they could pay from two sources. One was the remnant of their foreign trade; the other was borrowed money loaned by a trusting outside world, including the United States. But the fatal defect of their situation is that they manufacture little or nothing that cannot be produced as well or better and at least as cheaply in other parts of the earth. Even more fatal is the fact that in order to manufacture at all they must first import much if not most of their raw materials, to which the labor of their workmen merely adds an increment of value for reëxport. There being no outside markets in which German products have an assured preferred status, the values added by German labor to foreign raw materials can be disposed of only at prices that are beaten down by ruthless competition.

Under this state of facts the German national economy has been gradually approaching the inevitable base-level prescribed in the nature of things for marooned populations. For the past several years German foreign trade has been characterized, on the whole, by shrinking volume and an unfavorable balance. During the earlier post-war period German imports could be financed in part by the proceeds of foreign loans, but as German credit dried up and new loans became unobtainable business could still be financed by omitting to repay obligations owed to foreign creditors. Now that the end of that rope

has been reached German economics have practically attained their foreordained base-level. The Germans can import nothing they cannot pay for in cash or obtain by barter; at this writing they have practically no cash, and so can hardly buy from any country that does not buy in equal amounts from them, regardless of price. Beyond what can thus be scraped together the Germans must be content with what has been left to them by a lost war. Having now little or no foreign outlet, the excess of their population, accumulated since they crossed the threshold of Malthusianism in the heyday of their national prosperity, is exerting its full pressure on the native soil.

In the situation to which the Germans have been reduced, the pressure of their population falls in the first instance on the supply of agricultural products. There is currently (1934) a shortage of about 25 per cent in general agricultural production,* and aside from trivial amounts of flax and wool there is practically a complete shortage of native materials for clothing. The shortage of food has to be made good at all costs to avoid the starvation that plagued the

* Bull. *Hamburg World Economic Archives*, No. 4 (1934), p. 10. The same authority estimates (p. 11) that to make good the combined shortage of fats, carbohydrates and proteins the area now in grains would have to be increased 15 to 20 per cent. This would still leave the great shortage in fibers and many other organic raw materials unaccounted for. The launching of the new "production campaign" by a National Farmers' Congress at Goslar in the summer of 1934 has served to emphasize the grievous burden of the agricultural deficit.

Germans during the war, and the need for clothing is hardly less imperative. The shortage in these essential materials is therefore a first charge against such foreign exchange as can be got together. But what must be spent for food and clothing leaves that much less for the purchase of foreign raw materials with which to keep the export industries going, and at this writing the national resources are not wholly covering both objects; in addition to unemployment due to the general business depression there has been unemployment growing out of a deficiency of materials for the factory operatives to work on. The government has found it necessary to introduce forced production of domestic raw materials and the exploitation of marginal resources of all sorts, regardless of cost in the ordinary economic sense; forced labor is being organized for reclaiming any waste land that might produce a crop; housewives have been required to salvage fats that would otherwise be thrown out; systematic collection of acorns, chestnuts, beechnuts and other previously disregarded edibles has been started, etc.

It is unnecessary to further enlarge this picture of a vast population, tightly marooned on a restricted area, weighted down by a Malthusianism that has now definitely come to a head, enduring a penurious present and facing an apparently hopeless future. On the one hand is the certainty, now acknowledged by authoritative Germans, that for them world trade has permanently lost its former dominant importance because of the industrialization of raw material coun-

tries and the disappearance of unprotected markets; German goods now have free or preferred entry nowhere, and even where there is a fair field the Germans are competitively hardly a match for the Japanese, who are under a pressure of population even more terrific.

And on the other hand is a domestic agriculture that has not yet risen to the occasion.

However, the Germans do not regard themselves as finished, and are not so regarded by their uneasy neighbors. They are still the largest homogeneous population unit in Western Europe. They have 50 per cent more indigenous man power than the most populous nation that touches their borders, and once they have made good their infractions of the Versailles Treaty and have rebuilt their military machine they could account for any of their neighbors, taken singly. Only by another powerful combination could they be held in check, but who knows what opportunities may lie ahead for making combinations useful to Germany, and for making another bid for at least an approach to a *Weltmacht* that will offer prospects of an easier living for their straitened millions? As matters now stand the Germans seemingly cannot avoid sinking to a lower level of existence unless the wall that encloses them melts away, or is blown up. Such considerations, reënforced by national self-esteem, offer a sufficient explanation for the remilitarization of Germany, ostensibly as a defense against being robbed of what is still left to the Germans but no less certainly to improve the first occasion for re-

covering what has been taken away from them, perhaps with compound interest. What is now transpiring may be nothing more or less than the beginning of another cycle—a new but no different phase of man's eternal struggle to live in spite of, if not at the expense of, his fellow man.

How to break up this vicious cycle has puzzled the philosophers, statesmen, humanitarians and religionists of all ages; and the modern swarm of peripatetic pacifists is still busy with the idea that war might be done away with by preachment and general sweet reasonableness, if not by unreasonable and unreasoning refusal to fight or to bear arms, or by votes against armaments. But the cause of peace gains nothing by shutting one's eyes to the fact that war has at least one constructive function: it may, if successful, rescue a population from the shadows of a deepening Malthusianism. Whether they rescue themselves by thrusting other groups deeper into the Malthusian shadow is beside the point; to justify itself the successful group has but to cite the first law of Nature, which is the law of self-preservation.

So, then, if a new German explosion is to be averted, it must first be made unnecessary; it is too much to expect a virile population of 65 million to submit tamely to the social strangulation that now awaits them, but public opinion of a war-hating world should insist on German self-help. The practical problem is to induce the Germans to think less of hacking their way out with the sword, and to think more effectively of engaging in a bloodless and in-

finitely more promising struggle with Nature within their own borders. Their foreign trade now barren of either present or future prospects for supporting an industrially top-heavy social-economic structure, and being reduced to a choice between renewed war, social strangulation, and autarchy, they will make no mistake by throwing their energies into an intelligent autarchy. The Germans have indeed already begun to make a virtue of necessity, and have established a number of marvelous *Ersatz* industries to replace now unobtainable foreign goods. But even an *Ersatz* industry must have something to work on, and for raw materials the Germans now have no sure recourse except their own soil. Thus again we come around to the fact that in Germany, as in many other parts of the world, agriculture is still in the hands of a bankrupt agronomic science.

What a pragmatic pacifism would suggest is that the Germans devote a sufficiency of their genius for organization and detail to reconstructing their agriculture along agrobiologic lines, and thus settle their food and raw material problem for the next several hundred years. They now have a total of 73.4 million acres of land under cultivation, which is twice as much as the British have, and one and one-half times as much as the Italians; of this cultivated land 51.2 million acres is actual plow land (not counting vineyards, orchards or truck patches), and 20.4 million acres in grass meadow and pasture. It is superfluous to go through the same agrobiologic calculations we have just applied to the agricultural and population

problems of Great Britain and Italy. Having assumed that these last two nations could supply their every essential need for food and clothing in overflowing abundance from their own land, we shall very easily assume that the Germans can do likewise. Taking them by and large the ordinary German farmers get by ordinary agriculture from the German soil quite as much per unit of area as the ordinary British and Italian farmers do; and since, when the question of suitable agrotypes has once been settled, all questions of soil and fertilizer become secondary matters of known or ascertainable detail, there will be, agrobiologically, no reason at all why maximum crops of perultra or near-perultra agrotypes should not be produced in the one country as well as in the other.

Among the most serious shortcomings of German agriculture are its failure to provide an adequate basis for an indigenous animal husbandry, and its failure to cope with the textile situation; before the economic situation reached its present acuteness, much of the meat and milk consumed by the Germans was either imported or produced with the assistance of imported feed stuffs; these imports of stock feed, together with imports of wool and cotton, put a heavy drain on the country's scanty trade balance. But, referring to the considerations previously cited herein, if half of the 20 million acres of the German meadow and pasture land were skillfully subjected to the Woodman régime (now used by progressive farmers in many different parts of the earth, including the United States), the Germans could have all the beef,

milk, mutton and wool they could reasonably use at home and might have some for export, if they will sell cheap enough. For climatic reasons they could produce no cotton, and as an *Ersatz* for this southern fiber they are being driven to the use of artificial fibers made from wood. An eminently more satisfactory *Ersatz* for cotton is linen; 1½ million acres of German soil in flax under an approved agrobiologic régime would give every German fifty or more pounds of linen textiles a year.

Another grievous shortcoming of German agriculture is its failure to produce an adequate supply of fats. Potatoes, which is the main German crop, make an excellent feed for fattening hogs; if the German farmers under competent agrobiologic direction should raise the average yield of potatoes to more than 500 bushels an acre—less than half the known capability of this near-perultra agrototype—all Germans could have more than enough bacon and lard, particularly if the diversion of potato starch to alcohol manufacture for power purposes were stopped.

Once German agriculture has been reformed on agrobiologic lines so that every material need for food and clothing in Germany is adequately covered, Germany would be independent of any outside source of supply except for certain mineral products not supplied by her own mines, and for certain strictly tropical products that add much to the pleasure of living. To obtain these the Germans must always maintain some sort of trade contacts with the outside world. Further on we shall make some suggestions as

to how such contacts might be established and maintained; for the present we have enough to do to emphasize the importance, to the Germans themselves and to the outside world, of seeing that Germany becomes self-supporting in the vitals of existence. At this time, and for any foreseeable future in the world as it now is, the Germans are in what may well be called a desperate social-economic situation, and hence in the nature of things they are a menace to peace. But in proportion as the means of comfortable living become more abundant in Germany the pressure of her population can but decrease; there will then be little or no real reason why the Germans should push to the East or to the West on a piratical quest for a more abundant life than they can have at home. The surrounding nations, even if they do not themselves turn to the new agrobiolgy peaceably to enlarge their own scales of living, will breathe easier to see their dreaded neighbor make herself more than content with what she has.

Herefrom a pragmatic pacifism, seeking an antidote for one of humanity's greatest afflictions, may well take its cue and throw itself into a campaign to induce and assist hard-pressed nations brooding over their wrongs to take the new, open road to peace with plenty.

This is not the place to set forth in detail the advice that might be given the Germans as to how they may go about enlarging their agricultural production. But there is one detail that will bear emphasis whenever the quantitative relation of population to

arable land comes up for consideration, and that is the efficacy of water as a promoter of national self-sufficiency. Had the Germans duly considered the subject of water in the days before 1914 they might have reached the conclusion that there was no real necessity for precipitating the Great War in the first place; had they made adequate provision for the use of water during the conflict they might have won the war; and now that self-sufficiency has been imposed on them as an inescapable necessity they should find in water one of the most valuable means for reaching that higher plane of existence which they can find only through developing their agriculture along agrobiologic lines.

In Germany, as in most other centers of civilization located elsewhere than in deserts, hardly any one ever thinks of agriculture otherwise than as dependent on incidental rain; the common man generally thinks that irrigation is for remote districts where there is never "enough rain."

But the fact is that there is never enough rain during the growing season, anywhere, for maximum agricultural production; this is true in Germany and in the wettest regions of the United States.

What the pre-war Germans, especially the higher-ups and the military men, did not realize was how easy it would have been to employ their unused water resources for wiping out the food deficit that was allegedly driving them into social strangulation. This oversight was not due to lack of available information on the subject, had they thought of looking into the

matter. We cannot here set forth this information *in extenso* and will content ourselves with a single exhibit, which we ask the reader to accept as representative. See Table VIII.

TABLE VIII.—YIELDS OF IRRIGATED AND UNIRRIGATED LAND IN GERMANY

Year	Rainfall, June-Aug., Millimeters	Unirrigated	Irrigated
		Potatoes in quintals per hectare	
1910	257	243	312
1911	98	78	264
1912	322	80	128
1913	227	168	204
1914	123	148	214
		—	—
Average ..		143	224
Oats in quintals per hectare			
1908	131	11.6	24.0
1909	47	15.4	30.6
1911	62	10.4	14.0
1912	215	29.6	35.6
1913	72	11.0	21.0
		—	—
Average ..		15.6	25.0

In words this table says that the average German summer from June to August yields enough rain to enable a hectare of German land to produce an aver-

age yield of 143 quintals of potatoes or 15.6 quintals of shelled oats, but that if summer irrigation is practiced the yield of potatoes may be increased about 56 per cent and of oats by about 60 per cent; other crops are benefited in similar proportion, even though the increased water supply is not accompanied by increases in fertilizer or other growth factors.

From this state of facts we may readily conclude that if the pre-war Germans had been intelligently concerned about their shortage of agricultural products, they might have avoided the darkening prospect of social strangulation by seeing to it that each year a sufficient area was put under irrigation to keep pace with the growth of their industrial population. There is no lack of waste water in Germany that might be used for the purpose, and the cost of thus equipping a million acres or more annually could have been met with an infinitesimal fraction of the cost of the lost war. But as a matter of fact the cost of providing facilities for irrigating cultivated land, where needed, is never a serious burden on either nations or individuals; seldom, if ever, do such facilities, if well managed, fail to pay for themselves from the start.

If it were the failure of the pre-war Germans to develop their resources that made the great military adventure necessary, it was omission to develop these resources that doomed this adventure to failure. The men who built the great German military machine credited themselves, and were credited by others, with a vast efficiency that left nothing unattended to; everything was supposed to be ready, down to the

last button. But it turned out that the war depended not so much on the last button as on the last potato. With thousands of people dying every day from starvation German resistance weakened first on the home front; with imports cut off the German soil could not feed both the army and the civilian population, and as the army had to be fed at all costs the civilians could but perish. The result might have been different had a sufficient area of land been equipped to keep alive the 800,000 Germans who starved.

Even now, with the Third Reich earnestly considering programs of increased production, there is little sign that the simple lesson has been learned. So far as now appears, about everything has been proposed for wiping out the German agricultural deficit except providing those things on which the yield of crops most depends; this is one of the concepts of Italian Fascismo that German Nazism has not imported. There is much wisdom of various kinds in Germany, but not yet a superabundance of agrobiologic gumption.

JAPAN

When we cross over to Japan we shall find a population problem with every element of Malthusianism present and acting.

The broad features here are: a population of about 66.3 million and a total area of tillable land amounting at most to 23.4 million acres, or about one-third of an acre to each inhabitant. When a comparison is

made with East's standard of 2.5 acres per person it may be inferred that the Japanese, if they have no other means of supplying the population, must get along with about a seventh of what, from an American standpoint, is the basis of a very moderate standard of living.

The social-economic conditions under which the Japanese population exists have been described in very many recent books, but for the purpose of the present discussion their situation may be briefly reviewed.

About half the population is directly engaged in agriculture, about a third in industry and about a sixth in trade. The agriculture is of a pronounced peasant type. There are about $5\frac{1}{2}$ million rural families, and 75 per cent of these families operate less than $2\frac{1}{2}$ acres of ground. About a third own their land; the rest are share croppers or pay money rent. Somewhat more than half of the cultivated ground (other than special plantations of non-food crops, as mulberry trees), is planted in rice, this cereal being the staple and preferred food of the population; wheat, barley, potatoes, vegetables and miscellaneous cultures occupy the remaining ground. There is practically no livestock industry. The total number of cattle (1930 census) is about $11\frac{1}{2}$ million, of which about half a million are dairy cows, or one milk cow to every 133 people. There are 24,000 sheep in the whole country, less than may be counted on a single large sheep ranch in Australia or New Zealand. There are about $\frac{3}{4}$ million swine, or one pig to about 90

persons. Cultural operations in the fields are carried on almost exclusively by hand labor, no animal traction being employed except on the few larger farms.

Except for fish, which is supplied by a fishing industry giving employment to about 1½ million persons, the Japanese are vegetarians, and necessarily so, because with only about a third of an acre of cultivated ground per inhabitant, the produce of the land must be used directly for human nutrition, and none can well be spared for feeding domestic animals. Even at that, the land is not feeding the population; there is now a permanent food deficit of 10 or 15 or more per cent, depending on the outcome of the harvests. But there is also a deficit of much else besides food. The deficiency in cotton production is reported as 99.9 per cent; wool 100 per cent; hemp and other vegetable fibers 81 per cent; oil seeds 68.8 per cent; the country is generally poor in mineral resources and certain other natural products; the deficits in iron ore, pig iron, steel, lead, copper, aluminium, tin, zinc, salt, petroleum, crude rubber and timber range from 33 up to 100 per cent. The shortage of these indispensable materials must be made good by imports from foreign sources, which means that foreign trade balances must be created in some way. The only native products of any consequence suitable for export are coal, cement, and raw silk, and these are far from able to meet the requirements.

In the nearly complete absence of native mineral resources, and with no real exportable surpluses of organic raw materials except silk, the only other pos-

sible means of creating foreign trade balances (aside from services such as shipping, tourist trade, etc.) is to import foreign raw materials to which the labor of surplus population may add an increment of value for reëxport to such foreign markets as may be open. Here is, in effect, the same precarious situation to be seen in some of the trouble-breeding areas of Europe.

The story of modern Japan is one of the marvels of latter-day world history, and most interesting to the students of population and sociology. Three generations ago this island empire contained a population that was practically stationary at about 30 million. For hundreds of years the country had voluntarily cut itself off from traffic with the outside world. Foreign traders were sedulously repelled. The population maintained itself without notable difficulty on its internal resources. Eventually, and somewhat forcibly, the Japanese were induced to establish contacts with Western civilization, much of which they proceeded to graft on their own; Western arts and sciences, and eventually Western industrialization, were adopted and applied on an increasing scale. Nor were Japanese borrowings from the West confined to the peaceful arts and sciences. They have always been more or less thankful to the Americans for their "awakening," but the manner of it touched and wounded their pride; when the foreigner's armada first appeared off their coast the inhabitants of that time would have much preferred to go along in the ancestral way, but Perry's guns spoke an unmistakable

language. From the first day of their acquaintance with the new world they began to acquire a new insight into the part played by military power in the destiny of nations, and they were not slow to perceive their own necessity for means of securing their national existence and for preserving their national dignity; Western munitions were among the first imports landed under the new dispensation, and along with foreign instructors in medicine and engineering came also instructors in modern military science.

Nearly simultaneously with Japan's awakening a profound change began to make itself felt in her population. From being almost stationary it began to increase. How much this stimulus to greater fecundity is ascribable to the newly-introduced Western amenities is a matter of doubt. Some writers gravely assert that it was the direct result of the new world outlook, that it sprang from a conscious national determination to achieve national man-power in the face of the foreigner, so that Japan might put from her the possibility of renewed foreign insult; thenceforth the rearing of children came to be looked on as a duty owed to the Emperor. In any case the record is unmistakable: from about 30 million this people has increased in 80 years to more than 66 million. The annual increase in the population is now more than one per cent, and meanwhile there has been a negligible increase in the area of land under cultivation. Here, indeed, is a perfect set-up for Malthusianism, and Malthusianism has not failed to come into its own.

So far as immediately concerns us at the moment, the dominant characteristics of pressure of population on the soil of Japan are mainly two: the extreme smallness of the holdings of the average farm family, and the superfluity of farm laborers. The great majority of the farms being less than $2\frac{1}{2}$ acres, and the average farm family comprising about six persons, more labor is available than is needed to tend the crops even when all the work is done by hand. Further, the produce of the farm is barely sufficient to furnish the most frugal of existences to those whose labor is really needed. A $2\frac{1}{2}$ -acre farm, if all planted in rice yielding 2,500 pounds of grain per acre, would give each member of a family of seven about $2\frac{1}{2}$ pounds per day. But yields of 2,500 pounds per acre are above the average, and much if not most of the best rice has to be sold to pay rent and taxes, and to pay for fish, clothing and other articles and services indispensable at even a very low scale of comfort. Meanwhile the stream of new lives continues to pour forth; every year it becomes humanly impossible for a certain excess of the population to live and work in the country, and these excess souls must find some other means of existence. So Japan's problem becomes one of caring for a constantly swelling number of people for whom work and food must be found in some source other than the native soil.

The ruling classes of Japan have long had this problem before them, and have sought solutions along familiar lines. In general, it is clear to every person who thinks on the subject that there are only two

conceivable solutions, either of which may or may not be practicable: (1) to settle the excess population in some uncrowded region, and (2) to create and maintain export industries. Solution (1) depends on whether there are any uncrowded areas that (a) freely admit foreign immigrants, or (b) can be made to admit them. There are now no important areas that freely admit Japanese immigrants, so alternative (a) is dismissed. Use of alternative (b) depends on the strength and effectiveness of the Japanese military establishment, and it is a matter of history that this establishment has succeeded in opening Formosa, Korea and Manchuokuo to Japanese settlers and Japanese trade. However, the expected movement of population toward these areas has not materialized; the Japanese proletarians show a disappointing reluctance to abandon their native soil to take up residence in regions where they would find a relatively harsher climate, and moreover would come into competition with an indigenous population living on a plane that is as low as, if not lower than, that on which they themselves exist at home. As means of relief for Japanese pressure of population the foreign territories that have come under Japanese domination are of importance chiefly to the extent that they afford unhindered access to needed minerals and additional sources of food, and also to the extent that they constitute controllable markets for Japanese manufactured goods.

There remains solution (2), which is to create and maintain export industries, and it is mainly into this

channel that the Japanese nation has thrown its surplus labor. The country being practically destitute of native raw materials except silk and a few minor mineral products, its export industries are necessarily founded on imported raw materials, chief among which are raw materials for textile goods, which under existing circumstances in world trade offer the Japanese the largest volume and the most rapid turn over; half the factories are textile mills and more than half the factory operatives are textile workers. It hardly needs to be reiterated that it is characteristic of export industries which are limited essentially to reworking foreign raw materials that they are doubly dependent on foreign markets, first to supply the raw materials and then to take the finished goods. A substantial portion of the trade balance created by the sale of the finished goods must be given up again for fresh imports of raw materials, and if difficulties arise that hinder reexportation the supply of raw materials automatically fails and the livings of the operatives in the export industries are imperiled.

The position of the Japanese population is all the more vulnerable because of the delicacy of the economic balance at home. The native soil is already carrying the maximum possible load, and at that is not producing enough food and clothing to maintain all the farmers and workers in what by Western standards is a miserable existence. The three billion yen of Japanese foreign trade support a sixth of all the workers; as one writer puts it, if this trade were cut off, one out of six Japanese must perish. This may

be an excess of pessimism, but it is certain that without the foreign income by means of which the food deficit is covered the standard of living of the Japanese masses must sink still closer to starvation levels.

In many respects the Japanese industries are, at the moment, well situated for developing an export business that will give employment to the surplus millions. In the first place, labor costs are extremely low, because the population is thoroughly accustomed to an inexpensive scale of living. The paternalism that runs through all Japanese life gives no scope to trade unionism. The proprietors of Japanese mills are thus able to underbid the prices of competing products offered in any Western country, and to cross tariff walls that are effectual bars to the goods of countries where higher standards of living, individualism, and trade unionism are powerful factors in keeping costs at high levels. The tale of the French pawnbroker and the Japanese bicycles is illustrative, if somewhat apocryphal. The story is that when 25-franc Japanese bicycles first appeared in a French town a local pawnbroker loaned 30 francs on each of several of these articles before an avalanche of offers awoke him to the real state of the market. But this policy of ruthless underbidding inevitably produces reaction. In the first place the foreign industrialists, thus rudely bearded in their own home market, move heaven and earth to lower their own costs. Here in the United States the electric light bulb case is illustrative. Cheap bulbs of Japanese manufacture were running away with the business of the General Electric Co., until

that great corporation put extra high pressure on its technical experts to devise bulb-making machinery so efficient that they could overmatch in economy even the cheapest of Japanese labor. Where such competition cannot be vanquished by improved technological efficiency it may still be disposed of by political leverage; the assailed home industries persuade their governments to raise the tariff wall, or to take other appropriate action. For instance, the British government, observing the rising flood of Japanese textile imports into the British colonies and dependencies, and seeing the Lancashire spindles idle and the Lancashire textile workers thrown on the dole, summoned the Japanese to a conference and compelled, or perhaps induced, them to agree to a division of markets that was satisfactory from the British standpoint. Thus are dams erected against the outflow of goods that mean life or starvation in one of the most highly saturated industrial population groups now on the earth. The pressure of population on the soil of Japan is being thrown back nearly everywhere except in the few remote, independent backward regions where industrialization has not as yet made much headway.

The need for markets permanently open to Japanese foreign trade is therefore of paramount importance to this marooned population group, which is visibly in the toils of an advanced Malthusianism. The game of hurdling low tariff walls and taking the native producers unawares must eventually be played out; the defenders contrive new fiscal weapons, or employ various devices of political *force majeure*.

What, then, could be more natural than that the Japanese should look for markets which they themselves can barricade against competitors? The detached observer who views the panorama in the light of reality finds no difficulty in comprehending the deep-seated motives behind the Japanese seizure of Korea and Manchuokuo and the systematic eradication of effective foreign competition in those areas. It is even not difficult to comprehend, and in comprehending to refer to the law of self-preservation, the Japanese punitive expedition against Shanghai in the hope of breaking up the Chinese boycott of Japanese goods that was imperiling the scanty livings of Japanese workers. Nor, for further reasons to which we are about to call renewed attention, is it difficult to forecast the future development of Japanese aims in the Far East. The almost casual announcement by the Japanese high command that if the Chinese leaders are unable to see eye to eye with the Japanese on matters under current discussion between the two countries, they (the Japanese) will be unable to guarantee against the recurrence of the Korean, the Manchuokuan and the Shanghai incidents, is not merely the blustering of an arrogant militarism, but the rumblings of a pent-up volcano of human need.

Pressure of the Japanese population would be far less a cause for worry either in or outside Japan if it were only static; if the statisticians could find, as they have found for many of the Western peoples, evidence of a decline in the net reproduction rate that would promise, in no great time, to bring the increase in

the numbers of the Japanese to a halt. Past increase has already gone far toward creating an insupportable condition, and if Japanese fecundity should suddenly become no greater than that of the French, for example, the situation would still be desperate; a superfluity of mouths to feed is already in being. Even so, the dimensions of the problem would become fixed, and the minimum of national income necessary to maintain the existing status would also become a stable quantity; the Japanese could calculate, for instance, what would be the minimum of new conquest on the Asiatic mainland required to keep their export business going at the present scale, assuming that they will eventually be barred from markets not subject to domination by Japanese arms.

But the pressure of Japanese population is not static; it is now the most dynamic of any on the face of the earth, at least in any region for which we have dependable statistics. The annual number of new births is a million or more, and this rate, projected into the future, conjures up an appalling picture; in ten years the population will be nearly 80 million, and in twenty years 90 or more million. Every year nearly half a million new workers appear to demand places on the already overcrowded soil, or jobs in mills the products of which are increasingly difficult to place in foreign markets. Truly, Japan may be compared, even more aptly than Italy, to a steam boiler under which the fires are becoming hotter and hotter and the pressure greater and more dangerous. An explosion surely threatens, unless the Japanese

accept starvation as the natural destiny of an over-saturated nation. They are not likely to resign themselves to such a fate without a struggle. Nothing else is to be expected than that they will—they must—proceed to the acquisition of new means of living by renewed penetration in the only region where they have a chance to dominate new markets and new sources of raw materials and food. It is inevitable that they will try to shut the Open Door in the face of populations like the British, the Russians and the Americans whose real needs, present or prospective, are not half as great.

Doubtless they have already weighed the hazards of confronting the white races in a struggle for the control of the markets of the vast Chinese region, and perhaps have measured the resistance they are likely to encounter from the Chinese themselves. At any rate, they cannot stand still, content if they can only hold the foreign trade they have acquired as of 1935. The ominously mounting pressure behind them will not suffer long delay in preparing for and undertaking a fresh search for larger and surer means of national life.

How will a pragmatic pacifism talk down such a conjuncture? Not by talk that merely fills the ears, but talk calculated to put more rice in the bowl, more of the real necessities of life in the huts, and relieve the stark need that forces the sale of girl children in order that peasant families may have somewhat with which to pay rent and taxes and exist a while longer; precisely talk that may help the Japanese people to

get with ease what they most need otherwise than at the point of the bayonet.

Some of the talking to be done must be addressed to other than Japanese ears, but leaving international aspects of the matter to the next chapter we may now say that in so far as the Japanese problem is objectively one of food and essential organic materials for the use of these swarming millions, the solution is completely in Japanese hands, and they need no foreign agrobiologist to prove it. The proof has been made on Japanese soil, by Japanese, and is completely valid even though, as written down, it shows no evidence of conscious use of the paraphernalia of mathematical agrobiology.

For example, I have before me a little yellow, paper-covered, eight-page pamphlet, $8\frac{3}{4} \times 6$ inches, that contains an authentic gospel of new life for this sorely straitened people. It bears the imprint of *Zaidanhojin Fumin Kyokai*, which on translation is found to mean "Better Farming Association, Inc." It is a sober, matter-of-fact, well-documented, record of practical field work in the growing of rice over a period of five years (beginning with 1928) in forty-five prefectures of the island empire, by 1,294 selected farmers, not more than thirty living in any one prefecture. As told in the pamphlet, the founder of the Better Farming Association was the late Mr. Hikoichi Motoyama, publisher of two of Japan's leading newspapers, the *Osaka Mainichi* and the *Tokyo Nichi Nichi*, no farmer himself, but a publicist keenly alive

to the critical situation of his race and minded to do something about it.

The Better Farming Association addressed itself in the first instance to the rice situation, rice being the Achilles heel of the whole Japanese social organism. The first step was the natural one of obtaining a measure of the full quantity of life that could be evoked in the rice plant. This measure was taken by making experimental cultures under what were considered to be the best possible conditions in various parts of the country. From these cultures it was found that the quantity of life resident in the rice plant as grown in Japan is equivalent to at least 209 bushels to the acre, which is only a few bushels less than the quantity of life found in Italian rice by Novelli. The Better Farming Association adopted 209 bushels to the acre as a mark to be shot at; prizes were offered and competitions were organized, only a limited number of the best farmers being admitted as competitors in each prefecture; the fields of the contestants were measured, and their produce weighed and tested by experts from the Imperial universities. The competitions extended over a period of five years. Nothing is reported to show that any of the competitors understood the theory of establishing a scientific agrobiologic balance on their fields, but they got results which the Better Farming Association compares with average results obtained by the common run of farmers of the same vicinities. See Table IX. In this Table, in column *A*, are exhibited the average results and costs of the best farmers, and in column *B* the average re-

sults and costs of the ordinary farmers. All figures are based on 0.1 hectare (0.247 acre) as the unit of area.

TABLE IX.—RESULTS OF GOOD AND ORDINARY RICE FARMING IN JAPAN

<i>Quantity harvested</i>	<i>1,564 liters</i>	<i>490 liters</i>
<i>Cost of production</i>	<i>A</i>	<i>B</i>
Seeds	yen 0.13	yen 0.25
Fertilizers	yen 6.71	yen 5.37
Various materials.....	yen 1.30	yen 0.61
Labor	yen 8.20	yen 9.66
Cattle labor	yen 0.43	yen 0.97
Miscellaneous expense..	yen 5.85	yen 11.92
Average cost of produc- ing 1 <i>koku</i> (180 l.)..	yen 22.62	28.88

The significance of the figures in Table IX are easily grasped. Where ordinary, average Japanese agriculture succeeds in obtaining one unit of rice, a more skillful agriculture can obtain more than three units.* No guesswork enters into this conclusion, because the results of plant growth are everywhere and always infallibly reproducible when the same conditions are repeated. This means that Japanese rice production can be expanded more than three times if all their average rice farmers become good rice farmers and are properly stimulated. The area under rice in the country is approximately 8 million acres. Multiplying yields per acre by three is equivalent to adding 16 million of *new*, clean acres of rice land to this

* $490 : 1564 = 1 : 3.19$.

excessively crowded island empire. Note also that the good rice farmers produced a unit of rice at a cost of yen 22.62, whereas it cost the ordinary farmers yen 28.88 to produce the same unit, which again shows that rationalized methods in farming not only increase the output but also lower the cost of the product and the price at which it can be sold to a needy populace.

Applying the same multiplier to the rest of their 23.4 million acres of tillable land, the Japanese could present themselves with the equivalent of 46.8 million acres of new farm land, sufficient to more than double the comfort of their present population and to take care of their new generations for many years to come. And this would be an acquisition which they would not need to share with any dense aboriginal population such as they will find in any region into which they have prospects of carrying their arms.

It does not yet appear that the remarkable demonstration of efficient rice agriculture staged by the Better Farming Association has had any appreciable effect on the gross statistics of rice production in Japan. As in the case of another famous gospel, the seeds of the gospel of a more abundant national life sown by Motoyama appear to have fallen, some by the wayside, some among stones, and some among tares; the stolid, plodding, unimaginative masses of the Japanese peasantry, routinized and case-hardened by centuries of rule-of-thumb practice, are not shaking off their torpor. In this they are not very different from masses of farmers much nearer home, even in

these United States, where dark-of-the-moon farmers are not wholly extinct—in fact are fairly numerous—in spite of the vast annual flood of reports and bulletins issuing from our fifty agricultural colleges and several hundred experiment stations manned by experts, themselves not wholly partakers of the new light of agrobiolgy; it is the exceptional American tiller of the soil who either understands or profits from much of the agronomic information so expensively laid before him.

The great service rendered to his countrymen by the departed Motoyama, through his demonstration that the dire Malthusianism which afflicts their beautiful land is not necessarily irremediable even though the whole world combine to keep the Japanese pent up in their narrow islands, has not yet borne its proper fruit. It is not an unfriendly outer world but their own inertia that halts the Japanese before the gates of a new abundance that lies plainly within their grasp. But it is also plain enough that the new salvation will not spring forth unassisted, else the gospel of Motoyama would already be showing results in the Japanese rice statistics. Not by precept, nor yet merely by conspicuous example, will the agriculture of Japan or any other nation rise *en masse* to the full agrobiologic height. But what does not materialize by the spontaneous reactions of millions of individuals may be evoked if these reactions are not wholly left to spontaneity. To develop the highest capability of the rice plant, or any other agrotype on which the social-economic destiny of the human race

or any section thereof depends, requires the conscious and sustained application of a high type of technological knowledge, skill and initiative which does not reside in a disjointed agrarian proletariat barely able to move under a crushing load of poverty. But this same proletariat, organized and knit together to form an integrated whole, and caused to act as a unit toward a definite end, may accomplish wonders. Left to himself, perhaps not one in a hundred Japanese rustics could qualify as one of Motoyama's good farmers; but put both him and his little farm under the authoritative direction of a good farmer and furnish him not merely with advice but with instructions to be carried out, together with all the material accessories of agrobiologic technology, and the food and organic raw material problems of Japan, with all that hangs thereon, would take care of themselves.

What we are suggesting is that the Japanese organize themselves to fight their Malthusianism, not by birth control which could have no immediate effect on the present condition of oversaturation, but by attack on the mentalities and attitudes that deny their soil its true fruitfulness. They have competently aped the Western nations in the organization of a vast military machine in which each of a million men knows his place, and without question does what is required of him; they provide these men with severely and expensively-trained officers and technologists of destruction, and have not omitted to devote yet more treasure to provide this vast military organization

with the material supplies and accessories of war; with this machine they plainly hope to shift a part of their troubles to other shores. We have no intention at the moment of advising the Japanese to diminish their military establishment by a single recruit, but merely to remark that there is nothing to prevent them from setting up a parallel organization, officered and administered with equal competence, for materializing the abundance that may be had for the taking. It has been demonstrated to the Japanese peasant that instead of 490 liters of rice per 10 ares he can produce 1,564; now let him be required to do it, not omitting, of course, to see that besides orders he shall have at his disposal the necessary water, fertilizer, etc., and also not omitting to see that he shall have his due share of the new abundance or its equivalent in wider means of existence. The necessary organization will be one competent and eventually extensive enough to blueprint the conditions on every tillable acre of Japanese soil, so that correct agrobiologic prescriptions may be written for every farm. This will require much supervision and routine scientific control for which, so far as this writer knows, neither the personnel nor the equipment as yet exists in Japan. Once the personnel has been created with the same care, with no greater expense than is being lavished on the education of military officers, the matter of bringing and keeping the whole of Japan's agricultural establishment up to the high standard envisioned for it by Motoyama will not be so difficult as might be supposed.

Is this suggested creation of what we may call an agrobiologic machine, involving the training of a sufficient corps of instructors and officials capable of imposing, from above, a scientific régime on the Japanese farmer, too much to ask of a nation situated as are the Japanese? It all depends on perspective and relative values. The Japanese are clearly faced by an imperious necessity of assuring the livings of their present population, to say nothing of the oncoming generations; this, surely, is a consummation earnestly to be desired, whatever the cost or whatever the method. They may do this by the classic method of seizing resources and trade now held by others, or by developing resources under their undisputed command. The one way is the way of war, a gamble with Fate, sure to raise opposition which the great and cruelly expensive Japanese war machine may or may not succeed in crushing. The other is the way of peace, with none to hinder; a bloodless struggle with a Nature that, in Huxley's phrase, would rather lose than win, involving no risks, sure to succeed.

Chapter VIII

THE PRICE OF PEACE

THE natural inference from what has been set forth in this book is that there is a plain road to peace through plenty—if nations can be induced to take it; and that it should be the business of a pragmatic pacifism to argue them into taking it. Surely it would seem that the argument which an intelligent pacifism might make, whether *ad rem* or *ad hominem*, is unanswerable and irresistible. Why go to war to obtain that which may be had without war? Assuming that every real national need can be satisfied without an appeal to force there is no reason for war that will stand the test of either common sense or of conscience.

The real mission of pacifism is less to cry down war than to cry up a substitute. The risks, the costs, the horrors of war are evident to every person with sense enough to be allowed a vote. There is little need for much effort to implant hatred of war in the minds of any civilized people. War is already well hated; and if it is nevertheless contemplated as an inescapable necessity it may be because the way of escape is not equally visible.

What is it that is required to cause nations to put

from them thoughts of war and rapine? Nothing else than a full command of the means of living—in the first instance products of the soil—that are denied them. By whom, or by what, are nations denied the means of full living? They are denied the means of full living, in the first instance, by their own incompetent agricultures that are failing to supply the populations with sufficient food and necessary raw materials. Why are their agricultures incompetent?

The reasons for the incompetence of the agricultures of nations that are foci of danger to world peace are mainly two. The primary one is that agricultural production is nearly everywhere in the hands of multitudes of small farmers who, in the mass, have very limited technical and material equipment, and operate their farms by rule-of-thumb and by grace of the weather; correspondingly, the effective result does not rise above a certain mediocre level.

On first thought the obvious correction will appear to be reëducation of the farmers along agrobiologic lines, qualifying each as a practitioner of agrobiologic dynamics. Indeed, from the standpoint of pacifism, nothing could be more desirable than the widest possible divulgation of agrobiologic knowledge; certainly those whose business it is to produce a nation's food, clothing and organic raw materials should be most fully informed as to the real natures and dimensions of the animate and inanimate factors of production, and as to how these factors may be harmoniously proportioned, each to the other.

Therefore we can designate, as one of the immedi-

ate objectives of a pragmatic pacifism, the divulgation of agrobiologic information, especially within those sore spots of the earth where agriculture is most obviously ineffective, and where pressure of population is most grievous.

However, the limitations of educative propaganda directed solely to the actual tillers of the soil are not to be overlooked. The average peasant of any country, soaked in tradition and folkway, is not easy to instruct even when the instruction is patently to his advantage. For instance, we may recall the previously noted episode of the Japanese Motoyama and his Better Farming Association, Inc. Here, if anywhere, is a body of cultivators that stands to gain by even a small increase in productive efficiency, in a land where an enlarged home supply of agricultural produce is a desperate national need. In this praiseworthy effort by an enlightened humanitarian the Japanese rice-growers of every prefecture had the opportunity of observing the best methods of master farmers; and what is the result? It is scarcely visible, if at all, in the statistics. A relatively few individuals may have profited from the conspicuous examples set before them, but Japan's rice problem has not thereby been solved; still less has it appeared that places are being made for the oncoming generations of Japanese whose pressure on the soil must inevitably produce, if not an outwardly directed explosion, then an inward one that will involve that island empire in the wreckage of communism or of anarchy. If Motoyama has failed it may be because his message did not

strike a vital spark that some other rouser of men might have struck, or may yet strike.

In other words, Motoyama's abortive crusade lacked that something which made a success of another crusade having the same objective under quite similar circumstances. We have also previously referred to the Italian Mussolini's *battaglia del grano* to which the leader of Fascismo summoned the Italian farmers for a struggle against the wheat deficit. It was a long struggle, lasting nearly ten years, but eventually resulted in *la vittoria del grano* by which, in 1934, the wheat deficit was covered. The difference here is that whereas the Japanese rice farmers were offered instruction, the Italian wheat farmers got instruction, plus inspiration that developed into mass enthusiasm; whereas the Japanese peasant does not appear to have been aroused to effective self-help by incitement addressed to his half empty stomach and all but bare back, the Italian *contadini* made the occasion not merely a private affair but also a national and patriotic service, which was to redress the nation's unfavorable economic position.

After all, perhaps the difficulty with Motoyama was not that he wasn't the right man, but that he was not in the right place. He was a private citizen, and did not personify the glory, the majesty and the spirit of the nation; he was not the object of that veneration and obedience that the Japanese reserve for their Emperor, whose slightest wish becomes a duty even to the lowest of his subjects, who would die for him. What if this august personage should lead his chil-

dren in a new battle for rice, as dynamic *Il Duce* led the Italians in their battle for wheat? There could be little doubt as to what the result would be.

What we mean is that if great commercial and military nations are experiencing difficulties in providing their citizens with food and their industries with organic raw materials from their own resources, the fault may not lie exclusively with the tillers of the soil; it may be because the nation's leaders do not lead. Indeed, the existence of a permanent food and raw materials deficit in any modern civilized country is *prima facie* evidence that the nation's leaders are not leading, are neglecting to unlock the springs of national feeling and action of which they are the natural custodians. It is they who, in the second instance, are accountable for the continuing incompetence of the national agriculture, and it is to them that the first arguments for better national agricultures should be directed. In so far as a pragmatic pacifism is able to influence public opinion it should be made plain that, so long as nations are failing to make intelligent use of the vast powers of organic Nature now at their disposal, they have no moral right to complain that they are hemmed in on an exiguous soil by rings of unsympathetic and selfish neighbors, or to demand, under threat of consequences that may be regrettable, a larger share of the world's wealth. It is not necessarily meant that deaf ears should be turned on a nation's plea for participation in overflowing natural resources in the possession of more fortunate nations, but no such plea can

be regarded as legitimate so long as it is demonstrable that the demands made upon others can be met by self-help on the home soil. What and how much any nation can produce by its own efforts is now known or is closely ascertainable by use of the yardsticks of agrobiology.

A pacifism that is aiming to attack war at its source through the gospel of self-help must therefore seek its first converts among those who are in control of the organs of national feeling and national action. In a movement of this sort, light for the salvation of peoples must first strike the top, whence it may pass down and be reflected from the bottom. If there be a genius at the top, he will need few hints as to how to set the ferment awork, and if he succeeds in enlisting enthusiasm in a common national purpose he will not be troubled overmuch by the forces of laissez-faire or economic liberalism, who will freely accept his orders and march under his banner.

The task of such a leader should be the less difficult the more his people are accustomed to authority and regulation in their public and economic affairs and the more autocratic his own position as the head of the nation, although it is not necessary to suppose that the most democratic of nations could not rescue itself from the circumstances we are considering, provided that the nation has leaders in whom it trusts and is willing to follow. But leadership there must be, to plan, to enthuse, to coöminate, and to direct. Where such leadership has an honest desire to lead the people along the path of peace to plenty, and

moreover has a clear conception both of the possibilities that lie ahead and of the means for implementing these possibilities, then the problem of international peace and the derogation of war can be well advanced toward solution.

How the possibilities of larger and safer national living are to be implemented is a matter of variable detail, depending on existing national set-ups and the sagacity of the leadership. But so far as we are here concerned the objective to be attained is the same for every case—namely, provision of all indispensable food and agricultural raw materials in amounts sufficient to cover the requirements of the whole population for comfortable living, and thus, so far as the national resources admit, to achieve independence of foreign supplies of those things, the lack of which creates the dangerous commercial mono-vacua that are the feeding-roots of war. By whatever administrative methods this independence is consummated, in the end it will be found that agriculture has been planned on a national basis; to each staple product there will have been assigned a certain fraction of the nation's arable land, calculated by agrobiologic yardsticks to yield a certain predetermined quantity sufficient for the national need, the cultivators being inspired to the patriotic duty of filling their quotas and making the soil yield the calculated amounts; of course, the cultivators will not be left without competent and adequate agrobiologic instruction nor will they lack an adequate supply of agrobiologic accessories, including water and fertilizers.

Undoubtedly reorganization of a national agriculture to the extent necessary to bring the efficiency of all the cultivators up to a point where every need of the nation for the products of its soil can be fully covered will require a corresponding reorganization of other branches of the national economy. Such reorganizations may put severe tests on both those that lead and those who are called on to follow because, the average man being what he is, much that is now left to *laissez-faire* and economic liberalism will have to go by the board. Agrobiologic science as a means of national or social-economic salvation is not self-realizing; it will need to be materialized not by a few but by the whole body politic. In fact, in view of the intolerable conditions to be escaped and the wider safety to be gained, it may be necessary and advisable to treat agriculture as the public utility it surely is, a really vital organ of national life that cannot be left to *laissez faire* embodied in ignorance, poverty, unenterprise, and dissociation of private interest from the public welfare.

However, it happens at the moment that some of the countries most in need of agricultures stimulated and controlled in the public interest are precisely those in which totalitarianism and authoritarianism have taken or are taking firm root. The principle of "general good above private good" in social-economics is not only preached but is also being put more or less skillfully into effect both by Fascismo and by Nazism, and in proportion as producers are being corporated and organized for unitary action (some call it

regimentation) laissez-faire and economic liberalism fade into the background with little or no effective public protest.

Here are national set-ups nearly made to order for the new era of peace with plenty. Let the leaders of such marooned, oversaturated groups as the Germans and the Italians become fully alive to the possibilities of national salvation that lie in the resources of Nature that may be unlocked by a thoroughgoing application of agrobiologic science, and let them use their new apparatus of totalitarianism to make the dream come true. One of the cardinal principles of totalitarianism, as understood by Mussolini, is that a property owner may be left in the management of his property so long as it is contributing its full quota to the national welfare, and not merely by the payment of taxes. A sounder rule of social-economics there cannot be, especially for oversaturated, hemmed-in population groups; and from now on it must be the function of an intelligent pacifism to help convince such peoples and their leaders that more is to be won through an intensive study of the general agrobiologic yield equation than by cramming into their manhood all the formulas of ballistics, poison gas, military aerodynamics, and all the rest of the deviltries of predatory warfare.

On the other hand, there is a limit to the possibilities of national self-help, in that not everything desirable for national full living can be produced within the borders of a single country, not even in so extensive a land as the United States, for instance. A

nation totally lacking in iron deposits cannot shake off the need for imports of this indispensable metal, although abundant native supplies of aluminum could be made to go a long way toward supplanting iron for many purposes. As yet no country of Northern Europe can well produce its own raw cotton, or rubber, tea, coffee, cocoa, spices, tropical fruits and dozens of other exotic products. Some countries have no native supplies of petroleum, but if they have abundant supplies of coal, lignite, or peat, or can produce large quantities of woody materials, it will not be impossible to shift without oil imports. But, all allowances made, nearly every nation must depend on outside sources for an irreducible minimum supply of certain commodities. And so the old question still rises to confront us: how are marooned groups to obtain essential foreign materials, if such goods as they are able to export are unable to cross tariff walls, and if they must forgo the use of armed force to satisfy their wants?

The shoe must now be shifted to the other foot. Let it be supposed that a commercially defeated nation, driven in upon itself, its export trade cut off by hostile fiscal measures and its oversaturated population faced with want, proceeds in good faith to reorganize its social-economy so that it may find its living on its own soil, supplying itself with all needed food and all the agricultural raw materials that its soil can be made to yield under the skilled care of able agrobiologists—yet finds itself short of essential materials produced only in a neighboring nation. To reduce

the case to its simplest terms, suppose that the neighboring nation in possession of the needed supplies is itself already producing every kind of goods produced by the needy nation, and that to protect its home industries from invasion of commonly produced goods it has erected prohibitive tariff barriers. Here we have, in essence, a typical mono-vacuum by which a militarily powerful group is kept marooned, and a dangerous pressure is created.

If the world ever evolves to a point where there is born an international moral sense between nations, as there is a moral bond between individuals, it will be recognized that a duty to promote peace lies on both the prosperous and on the needy nation. It may fairly be asked of the needy nation that it leave no stone unturned in a well-directed effort to make the most of what it has; that, if need be, it reorganize its social-economy so as to develop the maximum productive capacity of both its citizens and its soil; that, if it lacks foreign exchange with which to buy certain foreign materials, it make shift with equivalent materials which its own soil will produce in abundance. For instance, if it lacks subtropical cotton, it might do very well indeed with North temperate zone flax. In any case, considering the known extent of arable land in every important country on the one hand, and on the other the known resources of agrobiologic science, there is no valid reason why even the nations now the most densely populated may not feed and clothe every one of their citizens in a state of substantial comfort.

Still, the self-help that a marooned group might

accomplish by intelligent organization and well-directed work may not wholly cover the price of peace with plenty. As we have just remarked, no one country will be able to find under its hand all those things that contribute to the ease and comfort of life; and so long as a powerful group has wants clearly identifiable as legitimate it will not contentedly face its neighbors, who, if *they* also want peace, must be prepared to make up the deficit of the cost.

To make short work of concretizing the matter, suppose that Germany needs a million pounds of palm oil, a product of French African colonies, for its toilet soap. There are no German credits in France because, let us say, the French linen industry is thoroughly protected by a tariff. So the Germans, unable to export linen, and deprived of toilet soap with a palm oil base, nurse aspirations for an African colony of their own, perhaps at French expense. Should not the French give up a little in order to insure that they shall keep a great deal? Indeed, is not a satisfied, peaceful Germany worth a great deal to Frenchmen? Ask the French widows and orphans, *les mutilées de guerre*, the French taxpayers who foot the bills for a powerful army; ask the French citizens who live nearest the Rhine who can hear, in anticipation, the roar of German bombing planes and the devastating thud of projectiles spewed from afar by Big Berthas. Why not make it easy for the tightly surrounded Germans to get products clearly recognizable as necessities for home consumption? It need not mean a general reduction of the French linen tariff or giving

the German linen spinners a chance to invade the French linen market *en masse*; that crude proceeding may be left to those who hate tariffs—any tariff—on principle, and who have not yet learned the fine art of quota management. But the French might well set apart a definite small corner of their linen market, say five per cent, for the duty-free use of Germans or other foreigners seeking credits with which to acquire French special products, in return for similar privileges whereby the French might easily satisfy their own actual needs for foreign specialities. If we generalize this idea we shall find no horizontal lowering of tariffs essential for the protection of home industries in the mass, but a setting apart of definite small fractions of the home markets of every country for the unrestricted official use of foreign governments seeking credits for imports of materials their peoples would like to consume but are unable to produce at home. This should remove the last ground of complaint that any people is unable to obtain for its own use any desirable material produced anywhere on the face of the earth. No country need be called on to surrender a foot of territory, and no country would feel the lack of colonies, seeing that it is allowed to cover its actual needs of colonial products.

What this suggestion amounts to is that international trade be handled, as with gloves, in a manner befitting its nature as a disturber of international good will and as a potential breeder of wars. Let international exchange be as free as air—but only to the extent necessary to fill, from the outside, specific com-

mercial mono-vacua that cannot be filled from the inside, and certainly not to an extent that would materially affect the living of any worker in any home industry. Also, certainly not to an extent that will tend to create and to perpetuate such a condition as we now see in the cotton textile industry of Japan, for example, where vast amounts of raw cotton are imported and then reexported as finished goods to exert unlimited pressure on the home markets of other producers of cotton textiles. The sooner such abnormal conditions are rectified the better will be the outlook for international peace. But it must be done primarily by national self-help, with neighborly coöperation of other nations in command of materials not producible at home. In return for such help, which need not be unprofitable to the helper, it may fairly be asked of a populous nation that, having redressed the balance of its internal demand and internal supply, it exert itself to perpetuate this condition particularly by not allowing the re-creation of large groups of industrial workers who must live solely or even largely on an export trade—unless the nation is well prepared to reabsorb these workers within the framework of a comfortable national economy should the export trade be interrupted by adverse developments, likely to arise at any time in international economics; it should organize its industries primarily to supply the home market, not disdaining export trade, but still not allowing the tail to wag the dog; no nation should allow itself—or be allowed, so far as international action can prevent it—

to have an export business the loss of which would amount to national disaster.

In sum, what we propose, on the one hand, is that the Germans and other groups in like positions rescue themselves from their precarious situations by the agrobiologic development of their enormous latent resources of food and agricultural raw materials; and on the other hand that their neighbors join with them in arrangements to promote fuller living by the free circulation of exotically produced goods, through a well adjusted and controlled free circulation of commonly produced goods in specified directions, to the end that dangerous mono-vacua may be filled up. To bring about these two basic conditions for enduring international good will is, we submit, a program worthy of the best attention of an intelligent and sincere pacifism, and into the realization of which all haters of war may well throw their energies.

It may be admitted that in the present state of international economic anarchy the necessary reorientations will require strong and sagacious leadership, and that before the world can be well set on the road to peace with plenty much travail of the spirit will have been accomplished. But the task of a pragmatic pacifism is now fairly clear. Through discussion and agitation for some such program as herein outlined the world may be brought to see that peace may be had for a price far less onerous than that imposed by preparations for and endurance of war.

Appendix

CROP YIELD A PHASE OF THE MASS ACTION LAW

*(For those who would appreciate a brief outline of
mathematical agrobiolgy.)*

IN Chapter IV of *Nations Can Live at Home* the five universal principles or axioms of agrobiolgy were listed and described and the reader was shown how they are combined to arrive at a generalized, universal yield equation that encompasses every form of plant life so far investigated (including all those that are of most importance to civilization), and every factor that has a measurable influence on the growth and yield of plants.

The object of this Appendix is to show how the universal yield equation is used to dimension, permute, control and bring to a finish those interactions of plants and their factors of growth that are of vital use to humanity, and also to show how the outer limits to the quantities of plant life are stated in figures.

THE WORKING FORMULA

As was stated in the text, the generalized yield equation is written in the form

$$dy/dx = f(100).c$$

when the result is desired as a percentage of the maximum possible yield. If the result is desired in units of weight the equation is written

$$dy/dx = f(A).c$$

where A represents the maximum possible yield in quintals per hectare.* In words the generalized yield equation says that the yield, y , of an agrotype growing in a particular closed system under the influence of graded amounts of a growth factor, x , is a function of the maximum possible yield of the agrotype in that closed system. It was also stated in the text that this function is asymptotic and has been identified as

$$(100 - y) \text{ or } (A - y).$$

The generalized equation thus assumes the form

$$dy/dx = (A - y).c,$$

and by integration is resolved into

$$\log(A - y) = \log A - c.x,$$

which is the everyday working tool of agrobiologists everywhere.

The entities represented by the symbols of this equation should be fixed in the mind; x is the amount

* In agrobiolgy it is customary and convenient to use metric units: the quintal (220.2 lbs.) as the unit of weight and the hectare (2.47 acres) as the unit of area.

of a growth factor in operation in a particular phase of the closed system in which the plants are growing; y is the yield of the crop corresponding to the amount of x in use, and A is the maximum yield that could be obtained if the amount of x were indefinitely enlarged; c is a constant factor of proportionality that determines the slope of the yield curve.

At this point it will be of interest to note how the agrobiologist goes about to ascertain the actual quantitative relations between plants and their growth factors and thus tests, in a practical way, the agreement between fact and theory. In general, the method is to study the effect of each factor separately while keeping all other factors in constant amounts and under standard conditions. In doing this a soil is prepared that contains a full amount of every essential growth factor except the one whose varying effects are to be studied. Then, to separate portions of this uniform environment there are added, for example, graded amounts of the growth factor nitrogen (N); the environment in all other respects remaining unchanged, any change in the growth or yield of the plants will then be due solely to the changes that were made in the amounts of nitrogen in action; the weights of the crops corresponding to these different amounts of nitrogen are recorded and used to plot the nitrogen yield-curve. Then a new series of experiments may be started in a standardized environment in which nitrogen and all the other factors are fully represented except phosphoric acid, the amounts of which are varied in the same manner, and a yield-

curve characteristic of this growth factor is obtained. A third series of similar experiments gives the characteristic potash yield-curve, and so on through the list of the known factors of plant growth. The yield-

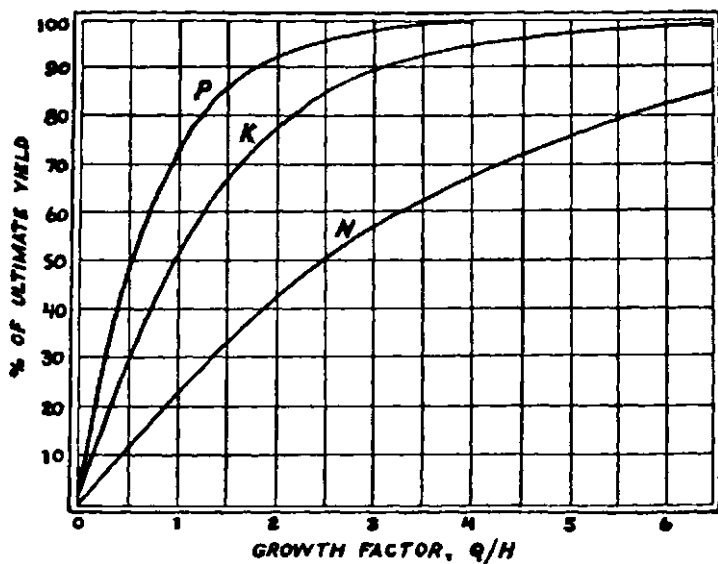


FIGURE 6. YIELD CURVES OF THE THREE PRINCIPAL PLANT FOODS—NITROGEN (N), PHOSPHORIC ACID (P), AND POTASH (K).

curves obtained in this manner show characteristic differences, as may be seen in Fig. 6, which shows the curves of the three plant foods that are consumed in largest amounts: nitrogen (N), phosphoric acid (P), potash (K).

The positions and forms of the three curves in Fig. 6 may be especially noted; it will be observed that their slopes are quite different; the K-curve rises

more steeply than the N-curve, but less steeply than the P-curve. This means that a given *weight* of N is less effective in promoting crop yields than the same weight of K, which again is less effective than the same weight of P; it also means that where the intention is to produce the largest possible yield the farmer or gardener must in general buy a larger amount of nitrogen than of potash, which in turn is required in larger amount than phosphoric acid, and these amounts must of course be used together and not separately; the correct proportions will appear below.

CONCERNING THE CONSTANT c

It was mentioned just above that the agrobiologist draws the yield curves of agrotypes by making rigorously controlled experimental plantings in a standardized environment with varying graded quantities of a growth factor. To each such curve there corresponds a particular working equation

$$\log (A - y) = \log A - c \cdot x$$

for which several values of y are known for corresponding value of x . By ordinary experimental methods and mathematical processes, which are fully described in standard reference books,* the value of c is found to be represented by

$$c = \log \frac{\frac{A}{A - y}}{x}$$

* Blancke: *Handbuch der Bodenkunde*, vol. IX, pp. 497-541 (1931). Verlag Julius Springer, Berlin.

When working with a certain growth factor, and when the work is done with due agrobiologic skill, it always turns out that c has the same numerical value for that factor, regardless of the kind of plant the experimenter is working with, and also regardless of whether the soil is rich or poor, provided only that it contains nothing directly harmful to the plants. In other words, in all computations by the working equation involving the use of a certain plant food or other growth factor, the constant c appertaining to this factor must be inserted in the equation.

The most probable values of c for the three main plant foods are: nitrogen, 0.122; potash, 0.33; phosphoric acid, 0.60; these values are statistical averages from numerous well-executed investigations under the most varied conditions.

When computing yields in cases where Baule units of growth factors (see below) are used, c has the value 0.301 irrespective of the nature of the growth factor or of the agrotype; this numeral is the universal constant of plant growth and yield.

DIMENSIONS OF THE OUTER FACTORS

It is next in order to find the agrobiologic dimensions of the outer factors of plant growth, such as the principal plant foods, for example. For this purpose use is made of the working equation in the form

$$\log (100 - y) = \log 100 - c.x$$

so as to find y as a per cent of the ultimate yield. Since the working equation is predicated on the

metric quintal as the unit of weight, x is expressed in quintals and the appropriate value of c is inserted. Taking a series of values of $x = \frac{1}{2}, 1, 2, 3, \dots$ quintals and using the nitrogen constant 0.122, it is found that the relations between quintals of nitrogen and percentages of the ultimate crop yield are as given in Table X.

TABLE X.—ABBREVIATED YIELD TABLE

<i>Nitrogen, in Quintals</i>	<i>Yield, in Per Cent of the Ultimate</i>
$\frac{1}{2}$	12.90
1	24.14
2	42.45
3	56.35
4	68.89
5	75.00
6	81.00
10	93.6
15	98.5
20	99.6
25	99.9

It will be noted that as the number of quintals of nitrogen added to the soil is increased, the percentage of yield increases at a continually diminishing rate in accordance with the law of diminishing increments, and for all practical purposes ceases to increase when the amount of nitrogen has reached 25 quintals per hectare. The yield is then virtually 100 per cent, and 25 quintals per hectare may be taken to represent the maximum useful dimension

of the nitrogen factor under any circumstances or with any agrotype; intermediate dimensions of the nitrogen factor and of the yields are as shown in the Table. In exactly the same way, by using the phosphoric acid constant 0.6, the maximum dimension of this growth factor under any circumstances and for any agrotype is fixed at not above 5 quintals, and by using the potash constant the maximum dimension of this growth factor is found to be 9.1 quintals.

In a similar manner the maximum and intermediate dimensions of all the other factors of plant growth are determined. But some of these factors, as light and agricultural warmth, are furnished by Nature in unalterable dimensions, except under greenhouse conditions; in the broad open fields they are already present in their maximum or limit quantities, and the farmer has simply to match their limits with limit quantities of other factors in which the environment may be deficient. On the other hand the maximum dimensions of certain indispensables, such as iron, manganese, boron, are so small (a few pounds per acre) that even the poorest natural soil will generally contain more than enough of them, so that they need be taken into consideration only in very rare cases; the same may be said as regards magnesia, silica and the rest, including lime; need for the latter may sometimes become acute, but this will be mainly for the purpose of correcting a sour condition of the soil. Like lime, water has a variety of agricultural functions other than as a constituent of plant tissues; as for water's maximum agrobiologic dimension in

practice, experience has shown that all reasonable requirements will be met when the moisture content of the soil is maintained at above 80 per cent of its water-holding capacity. Thus only the supply of nitrogen, phosphoric acid and potash are left for the farmer to worry about, and it is significant to note that the great fertilizer industry has practically no other stock in trade than these three plant foods in their various forms.

Herein lies a hint for the practical farmer or suburban gardener who frequently asks what is the best, and how much, mixed fertilizer to use. The answer is that since the Baule unit measures the relative effectiveness of growth factors, the most effective mixed fertilizer will be one in which nitrogen, phosphoric acid and potash are contained in the same proportions as their respective Baule units, which are 2.5, 0.5, and 0.91, or say multiples of the base formula 5-1-2. These proportions represent the ideal plant-physiological balance for crop-producing purposes when the soil to which the ideal fertilizer is added contains no extraneous circumstances inimical to normal plant growth; it is beyond the scope of this Appendix to discuss these circumstances. But assuming that the soil is normal and decently supplied with moisture, 5 tons per hectare (2 tons per acre) of a 15-3-6 mixture would not be an excessive amount to add to a soil that is rather poor to start with, especially if the agrotypes to be planted have high positions on the absolute scale of growth power. Even if the soil is slightly abnormal in some respects,

the use of the ideally balanced mixed fertilizer will be attended with less chance of failure than with one that is not ideally balanced.

DIMENSIONS OF THE INNER FACTORS

The maximum useful dimensions of the outer factors of plant growth being known, to obtain the maximum dimension of the power of life resident in any agrotype it is only necessary to establish an environment containing all the outer factors of plant growth in their maximum amounts; any agrotype planted in such an environment will infallibly display the utmost of its vital energy, expressed in its ultimate yield of dry substance. However, such a proceeding does not of itself define the position of the agrotype on the absolute scale of growth power, and so does not distinguish between perultra and subultra agrotypes. To establish this distinction it is necessary to employ the "rule of inverse nitrogen contents." *

In the process of making a series of graded additions of nitrogen, for example, to a soil that contains none of this plant food but is otherwise suitable for normal plant growth, there comes a point when enough nitrogen has been added to assure the production of half (50%) of the ultimate yield of the agrotype that would be obtained when the nitrogen has been raised to the limit. The amount of nitrogen

* This important principle of quantitative plant biology was first announced by the author in *Facts About Sugar*, issue of February 28, 1928, p. 158.

that will produce 50% of the ultimate yield is called one Baule unit of nitrogen, and is independent of the nature of the agrottype, i.e., it is the same for all agrotypes. Now, it is required by the equation

$$\log (100 - y) = \log 100 - 0.301.x$$

that when $x = 1$ Baule unit, $y = 50$; when $x = 2$ units, $y = 75$; when $x = 3$, $y = 87.5$, and so on *ad infinitum*, each succeeding Baule unit producing an increase half as great as the unit that went before.* The significant point is this: the first unit of nitrogen produces 50% of the total yield; most of this unit is taken up by the plants and incorporated in their tissues as protein, the rest being left in the soil. The second unit raises the yield to 75%; it causes an increase equal to half the product of the first unit, and so only half the second unit of nitrogen is removed from the soil by the crop; similarly, only a fourth of the third unit is used, and so on until less than a hundredth of the tenth unit is taken up.

Before proceeding further it may be mentioned that the value of a Baule unit, in quintals per hectare, is found by solving for x the equation

$$\log (100 - 50) = \log 100 - 0.122.x,$$

where 0.122 is the proportionality factor of the growth factor nitrogen; the value of x is thus found to be 2.5, or one-tenth of the limit effective quantity, 25 q/h, of this growth factor. The same equation,

* See Table III in the text.

with appropriate changes in the proportionality factors, may be used to find the value of the Baule unit of any other growth factor.

Now, the fact is that when a perultra strain of corn, for example, is grown in a perfertile soil along with an inferior subultra strain of corn, both strains having by nature the same *percentage* content of nitrogen in their dry tissues, the perultra agrotype will absorb from the soil a greater *total weight* of nitrogen than its subultra congener; in fact, the former strain, being perultra, will utilize the maximum possible quantity of nitrogen. We will now ascertain what is this maximum amount of nitrogen that can usefully be resorbed by perultra corn (or any other perultra agrotype) in one growth cycle.

For this purpose, instead of representing y as a function of x , we represent x as a function of y and write

$$x = \frac{2 - \log(100 - y)}{c}$$

which any mathematician can reduce to

$$dx/dy = 0.4343/100.c,$$

which gives the reciprocal of the tangent at the origin of the yield-curve of a perultra agrotype that is growing in a perfertile soil; the reciprocal itself is therefore

$$100.c/0.4343 = 100(0.122)/0.4343 = 28.1$$

i.e., in this case ordinates are to abscissas as 28.1 : 1. Since the tangent is a straight line and its equation is $y = mx$, when y has the value 100, i.e., 100 per cent of the perultimate yield,

$$28.1x = 100, \text{ and } x = 3.56.$$

The quantity 3.56, which ordinarily is rounded off to 3.6, represents the maximum quantity of nitrogen, in quintals per hectare, that can usefully be absorbed by a perultra agrotype in one growth cycle. Subultra agrotypes naturally absorb smaller quantities in proportion to their relative positions on the absolute scale of growth power.

The final step in this process of evaluating the maximum quantity of life that can be possessed by any agrotype is to relate its normal nitrogen content to its total production of dry substance. Like all other genotypic characters, the nitrogen content of a definite plant genotype that has been grown in a normal environment is a constant,* and is usually expressed

* A normal environment is one from which directly harmful or extraneous circumstances are absent, and where the soil contains the plant foods in Bauleic proportions; in that case the plant foods will all be exerting equivalent physiological pressures. But if the plant foods are not present in Bauleic proportions, those that are present in the highest concentrations will exert the greatest pressures and will be absorbed in the largest proportions; much of this excess absorption will be useless from the standpoint of additional growth ("luxury consumption"). For this reason the chemical composition of the plants will vary with the chemical composition of the soil (this is another phase of the law of mass action discussed

as a per cent; thus, the normal nitrogen content of a certain pure line strain of wheat is 1.25 per cent; the total quantity of nitrogen that can be absorbed being 3.6 quintals, dividing 3.6 by 0.125 gives the perultimate yield, in quintals per hectare, of a perultra strain of wheat (straw plus grain) of that nitrogen content. Since the ratio of straw to grain of a normally grown pure line strain of wheat is also a constant, if this ratio is known the perultimate yield of grain is also known. In this way it is ascertained that when its powers of life have been fully developed by the plant breeders the wheat plant, as we now know it, may be expected to yield about 93.6 quintals of grain per hectare, or 171.2 bushels to the acre. As was stated in the text, wheat has already been advanced on the absolute scale of growth power to a point where it can yield 122½ bushels to the acre, which means that 71.6 per cent of its potential quantity of life has been evoked, with prospects of soon reaching the perultimate limit.

The theoretical perultimate yield of any agrotype can be calculated in the same manner; from the standpoint of ordinary agriculture the results of such calculations are truly astonishing, and no less astonishing is the fact that the predicted yields have been obtained or closely approximated in actual field practice.

in the text). But the composition of the plants is always the same for the same system, normal or abnormal; in the discussion of principles reference is always to the normal or optimum agrobiologic condition.

MASS ACTION AND CROP YIELDS

So much for the basic entities with which the agrobiologist has to work—the inner and the outer factors of plant growth and yield. It is next to be shown how these entities may be permuted and controlled in practical agrobiological according to the principles of agrobiological dynamics, a science that takes its rise from the fact that the interaction between plants and the factors of their growth is a phase of the general mass action law, which may be explained in connection with the formula:



This formula may be read as follows: When a certain amount of an active substance, *A*, is added to a certain amount of another active substance, *B*, the result is a product, *C*, the amount of which is determined by a factor, *k*, that measures the degree of activity between *A* and *B*. In our case, *A* may represent a factor of plant growth and *B* the inherent power of life possessed by an agrotype. We already know that as the quantity (concentration) of a growth factor is increased, an increasing amount of life is evoked from the agrotype, and so the yield, *C*, is increased until the limit quantity of *A*, as determined by *k*, has come into action. On the other hand, leaving the amount of *A* as it is, and increasing the stand (density of planting) of *B*, or substituting for *B* a series of other agrotypes with larger and larger quantities of

life the yield C is again increased. Or, by simultaneously decreasing A and increasing B , or vice versa, the factors may be varied while keeping the yield constant. Thus is the yield of crops manipulated by controlling or varying the active masses or potencies of the basic factors.

SIMULTANEOUS VARIATIONS OF GROWTH FACTORS

In the foregoing simplified explanation of mass action as applied to the yield of crops, A was regarded as a single growth factor. But there are several indispensable factors of plant growth which may simultaneously be increased or diminished in the same or different senses, either purposely or by accident. The great number of such possible combinations would seem to make control of the yield of crops in the open fields a very complicated affair.

However, any such variations can still be assigned specific dimensions by using a further development of the working equation

$$\log (A - y) = \log A - c.x.$$

When this equation is delogarithmized it may finally appear as

$$y = (A - 10^{-c.x})$$

which represents the action of a single growth factor which has the proportionality constant c and is used in the specific amount x . When there are n variable

growth factors, having the proportionality constants c_1, c_2, \dots, c_n , and present in the amounts x_1, x_2, \dots, x_n , the formula for the joint yield, y_n , becomes:

$$y_n = A_n (1 - 10^{-c_1 \cdot x_1}) (1 - 10^{-c_2 \cdot x_2}) \dots (1 - 10^{-c_n \cdot x_n})$$

This seemingly complicated formula is very easy to manage in practice when it is remembered that the expression

$$(1 - 10^{-c \cdot x})$$

represents the percentage crop-producing value of a growth factor when its amount, x , is given in Baule units. Thus, for example: Suppose that the amount of x_1 is 3 Baule units and x_2 is 2 Baule units; now, we know that 3 Baule units of any growth factor will produce 87.5 per cent of the ultimate yield of any agrotype when the growth factor in question is the only deficient factor in an otherwise complete environment, and that 2 Baule units of any other growth factor will produce 75 per cent of the ultimate yield under the same condition. When both are deficient and are acting in the stated number of Baule units their joint effect will be

$$0.875 \times 0.75 = 0.655$$

and the crop will be 65.5 per cent of the possible maximum. Thus by ascertaining, through the use of approved methods, the number of Baule units of

each growth factor in any closed agrobiologic system, the crop-producing value of that system is known beforehand, and can be changed by modifying the number of Baule units of any factor in action. The production of a crop may then become as routinized as putting up a house from the architect's plans. This assures that the agrobiologist who has the means of "blueprinting" the conditions with which he has to deal, and who is in command of the necessary agrobiologic materials, can take and keep complete control of any agricultural operation.

PRACTICAL EXAMPLES

As an illustration of the scope of such control consider the following example:

A soil that is otherwise perfertile and well-watered is found by an accurate fertility survey to contain 1 Baule unit of nitrogen, 3 Baule units of phosphoric acid, and 3 Baule units of potash; it is purposed to grow in this soil a variety of sugar beets that rates 80 per cent on the absolute scale of growth power and contains an average of 0.2 per cent of nitrogen in the fresh substance; the ratio of roots to offal is 2 : 1.

- (a) What is the indicated yield of factory beets at a density of planting of 2.4 Baule units, and what will be the average size of these beets?
- (b) What is the indicated yield and average size of the beets when the phosphoric acid and potash of the soil are left as they are, the nitrogen increased to 2 Baule units and the density of stand to 3 units?

(c) Specify the conditions under which a yield of 500 quintals per hectare of factory beets may be obtained in any climatic region where beets may be normally developed.

(a) Taking the percentage crop-producing values of 1, 3, and 3 Baule units of nitrogen, phosphoric acid and potash, respectively, and multiplying them together, the fertility index of the soil as it now stands is

$$0.50 \times 0.875 \times 0.875 = 38.28\%$$

The perultimate yield (whole plant) of an agrotype with a nitrogen content of 0.2 per cent is $3.6/0.002 = 1800$ quintals per hectare. As one-third of the total crop will be rejected as offal (tops) the perultimate yield of factory beets would be 1200 q/h if the soil were perfect and the stand 10 Baule units. But the agrotype rates only 80 per cent, the fertility index of the soil is only 38.28 per cent, and the stand is only 2.4 units, corresponding to a crop-producing value of 81 per cent. The indicated yield of factory beets is thus

$$0.80 \times 0.3828 \times 0.81 \times 1200 = 294 \text{ q/h.}$$

If there are 26,500 beets in one Baule unit of stand the average weight of the beets will be 461 grams.*

* The optimum density of planting (number of plants per hectare) is a genotypic character distinctive of each agrotype.

(b) Changing the set-up so that the soil will contain 2 Baule units of nitrogen raises the fertility index of the soil to

$$0.75 \times 0.875 \times 0.875 = 57.42\%$$

and by raising the stand to 3 Baule units the indicated yield is

$$0.80 \times 0.5742 \times 0.875 \times 1200 = 482 \text{ q/h}$$

and the average weight of the beets 606 grams.

(c) The magnitude of the crop of a variety of sugar beets is simultaneously a direct function of the position of this variety on the absolute scale of growth power (expressed as a per cent of the perultimate yield), a linear function of the fertility index of the soil (this index is compounded from Baule units of growth factors as above described), and a logarithmic function of the density of planting expressed as Baule units of stand. Let A represent the theoretical perultimate yield (determined as aforesaid), g the position of the agrotype on the absolute scale of growth power expressed as a per cent of the perultimate yield, f the fertility index of the soil previously calculated as described, and B_n the percentage crop-producing value of the number of Baule units of stand employed. The formula for a crop of 500 quintals per hectare is then

$$500 = A.g.f.B_n.$$

The factors A, g, f, B_n may be varied at will in different senses so long as their joint product satisfies this equation, provided that the elements of soil fertility are not varied so widely *inter se* from the normal physiological balance that the law of conflicting attributes comes into play; this brings into view a further extension of the subject that need not be considered here, except to say that this new extension is also subject to mathematical definition and control.



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