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RECENT ADVANCES IN PASTURE MANAGEMENT

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PREFACE.

THE publication of this Monograph comes at a time when the Empire is on the verge of a great speeding-up in the development of its grassland resources. Grass, as Dr. McConkey points out, is our most valuable and hitherto perhaps our most neglected crop.

In the last few years a scattered group of scientists (for whom a new name, "agrostologists," has been coined) has been following, systematically and patiently, the numerous and often confusing lines of approach towards a central goal—the improvement of grassland. It is not easy for the farmer or layman to follow the progress of this new movement, in which so many different sciences play a part. This Monograph, therefore, is particularly opportune. It describes simply and lucidly recent discoveries and the present position of grassland research. It provides, as it were, an aerial photograph of the lay of the land and the disposition of the troops.

Dr. McConkey is particularly fitted to undertake this review. During two years' leave from the Guelph Agricultural College in Ontario he has studied at Cambridge, and also at Aberystwyth, Aberdeen and other grassland centres in this country, and has obtained a first-hand knowledge of similar work in many Continental countries. It is, moreover, appropriate that the task of outlining what has already been achieved should fall to a scientist from the overseas Empire, where so much of the finest grassland work is being done.

Scientists, always cautious in their estimates, have said that the productive capacity of the Empire's pastures may be doubled by the use of new grasses scientifically evolved and by new methods of management. The Empire Marketing Board has been able to give financial support to the breeding of high-yielding and hardy strains of grasses at Aberystwyth and at Palmerston North, New Zealand, and also to studies of the nutritive value of pastures at Aberdeen.*

* See "The Composition of Pastures," by J. B. Orr, D.S.O., M.C., M.A., M.D., D.Sc. (E.M.B.18.)

The publication of this Monograph is intended as one more contribution by the Board to the cause of Empire pastoral progress. Work has now definitely passed the experimental stage when the scientist must avoid publicity. He has found out something about which it is his duty to "tell the world." I should like to see this Monograph in the hands of every farmer and every individual interested in Empire development. It is essential that farmers, public men and laymen should have a clear idea of what has already been done, and of the great things that may be achieved in the next few years with the powers which science is now giving to the pastoralist.

T. DRUMMOND SHIELS,
Chairman of the Research Grants Committee.

Empire Marketing Board,
March, 1931.

INTRODUCTION.

ALL the world over, everybody interested in agriculture—statesmen, farmers and scientists—have been giving greatly increased attention during recent years to matters connected with grassland. This is not to say that grasses and grassland have been quite the Cinderella of agriculture. Practically 100 years ago Peter Lawson of Edinburgh had appreciated the differences that existed between different strains of one and the same species of grass, and through the intervening years there have not been lacking pioneer landowners, pioneer seedsmen and pioneer scientists who have done yeomen service for grassland. The point of view has, however, shifted and widened, and to-day the problems of grassland are the subject of critical study and of critical interest of a character altogether more purposeful and constructive than formerly.

Having regard to the importance of grassland to the British Empire as a whole it is not without significance that the pages that follow should have been written by a Canadian who has spent two years in Europe with the explicit purpose of studying recent developments in grassland research. Dr. McConkey writes in the spirit of the present scientific attitude towards grassland—and he writes with knowledge and discernment concerning the trend and implications of the manifold lines of work with which he has made himself acquainted, both in this country and on the continent of Europe.

The picture Dr. McConkey draws has probably gained something in both clarity and unity from the fact that he was naturally looking at European work and conditions chiefly with a view to grasping general principles which might advantageously be applied to the grassland problems of Canada—and not with a view to assist him in the conduct of a particular line of grassland research in this country. But be that as it may, the result is a report that can hardly fail to interest all who have the welfare of agriculture at heart—and a report which will prove of real value and assistance to investigators throughout the Empire who are concerned with the problems of grassland.

R. G. STAPLEDON,

Director of the Welsh Plant Breeding Station.

Aberystwyth,

December, 1930.

THE DEVELOPMENT AND RECENT ADVANCES IN PASTURE MANAGEMENT.

THE grasslands form one of the greatest natural resources of the British Empire, a resource which has been woefully neglected in some parts of the Empire through lack of interest and knowledge. Happily, recent experiments show that nowhere in crop husbandry can greater increase in yield and quality be secured by proper management than in our grass crop, the most important crop resource of the Empire.

There has been an amazing apathy on the part of technical workers as well as laymen with respect to research in meadow and pasture methods, and the economic grasses and clovers, typified by the layman's remarks when you say you are studying grass—it is just grass to him and nothing more—little he realizes the wealth of biological forces at play in a pasture field ; the different species struggling for survival against the grazing animals ; the genetics, physiology, light relations, biochemical, and nutritive problems involved. But it is a pleasure to record that this apathy is giving way to a marked interest and very definite practical advances have been made in the last ten years.

Pasture is the raw material for the formation of milk, butter, cheese, meat, mutton, wool, hides, and other products of cattle and sheep. All these products have a very intimate relation to our life day by day, and form a major part of the trade and commerce of the Empire.

IMPORTANCE IN THE DOMINIONS.

Grassland products form (1) :—

94	per cent. of the total exports of New Zealand
60	“ “ “ “ “ “ “ “ “ “ Australia
55	“ “ “ “ “ “ “ “ “ “ Irish Free State
41	“ “ “ “ “ “ “ “ “ “ South Africa
17	“ “ “ “ “ “ “ “ “ “ Canada

while 64 per cent. of the agricultural production of England and Wales is derived from grassland. Of the total area of 47 million acres cultivated land in the British Isles approximately 34 million, or 70 per cent., are covered by permanent and temporary grass leys.

Trade and Consumption in the Empire (2).

The total annual consumption of grassland products in the United Kingdom reaches the enormous sum of £375,000,000, or nearly £10 per capita, while that of wheat is only £100,000,000.

Total annual imports of grassland products to	£
United Kingdom	250,000,000
Total annual imports from the Empire	150,000,000
Total home production	125,000,000

leaving a balance of £100,000,000 to be developed in the Empire.

The limiting factor for the production of these products is not the number of cattle and sheep, which can be increased indefinitely, but the raw material which they transform. Grass, therefore, is a subject of research which is pre-eminently worthy of intensive work on an Empire basis.

Meat Situation.

The serious need for expansion of the meat-producing industry within the Empire is patent to all, dependent as we are upon the foreign producer in whose markets competitive buying is steadily increasing, particularly from U.S.A.

Could anything be more practical and sound at this time, when efforts are being made to develop inter-Empire trade, than the development of the grassland resources of the Empire, gaining thereby in industry and a more independent position with respect to our meat supplies ?

One of the first impressions of a Canadian visiting England is the apparent low consumption of fresh milk, and the difficulty of securing fresh cool bottled milk in restaurants and homes.

A very thorough study by Forrester (3) reveals that the per capita consumption of fresh milk in Britain is estimated at about one-third of a pint per day ; a very small amount, and low in comparison with other countries, for example :—

Country.	Year.	Estimated consumption per head per day. Pints.
Switzerland	1925	1·83
Sweden	1924	1·48
Denmark	1923	1·25
Norway	1920	1·13
United States of America	1925	1·00
Netherlands	1923	·42
France	1924	·33
England and Wales	1926	·33
Germany (Berlin)	1923	·30

An examination of the above data reveals that here is an opportunity for developing this potential home market by marketing a higher grade, standard, fresh, cool, bottled, product which does appeal to the consumer, as borne out by experience in Canada and United States of America.

Not only would such a development be directly beneficial to the health of the nation, but it would be a practicable step in relief of the agricultural depression when so much land is going down to grass, in a country where flourish some of the finest natural pastures to be found in the world.

Unlike a mine, which gradually "peters out" as it is worked, pasture is a natural resource which increases production with good management.

CO-ORDINATED EMPIRE RESEARCH.

For the first time in the history of Agricultural Research there has been a strong co-ordinating influence felt throughout the Empire. Grassland studies have been the basis of this co-operative effort in Empire research. This has been due notably to the efforts of the Civil Research Committee of the Cabinet, the Empire Marketing Board and the Imperial Agricultural Research Conference of 1927.

The research initiated by Major Walter Elliot and Dr. Orr of the Rowett Research Institute, Aberdeen, Scotland, on the mineral deficiencies in pastures, is now well under way in the United Kingdom, Colonial Africa, South Africa, New Zealand, Australia, Canada, besides in outlying parts of the Empire, i.e., the Falkland Islands.

This work has tended to draw attention to pasture research and has stimulated effort in all directions on grassland studies.

Almost simultaneously with the above work, the late Professor T. B. Wood and Dr. H. E. Woodman, of the Animal Nutrition Institute of Cambridge University, initiated their epoch-marking research on the nutritive value of pasture, and the conservation of green grass in the form of dried grass cakes, a valuable high protein concentrate for live stock.

The war gave a great impetus to the process of manufacturing synthetic nitrogen, and in the reconstruction of the industry in the post-war period these plants and processes have been utilized to make nitrogenous fertilizers at lower than pre-war cost, and with the added advantage of the prospect of an unlimited supply.

II

Imperial Chemical Industries Limited, alive to this development, formed a subsidiary company, Nitram, and a research station at Jealott's Hill, Maidenhead, to investigate the commercial and scientific possibilities of the application of synthetic nitrogenous fertilizers on grasslands.

Directed from these central institutions an elaborate system of experiments is being carried out on farms throughout Great Britain.

These experiments are based on the German Hohenheim method of heavy fertilizer treatment and rotational grazing, an intensive system of grassland management. Accurate costings of the production of milk, beef, and mutton are being worked out; a similar programme is being pursued throughout the Empire.

Many farmers, government departments of agriculture, experiment stations, and colleges in the Empire have taken the cue and are trying out the New Rotational System of Grassland Management, so it is being thoroughly tested.

This modern production of cheap synthetic nitrogenous fertilizers marks a change in agricultural practice. Everywhere one goes in Europe the experiment stations are endeavouring to breed strains of grain which will stand up under heavy nitrogenous manuring, and are experimenting on the influences of varying increments of nitrogenous dressings on yield of crops.

The Intensive System of Grassland Management is the expression of this modern development as applied to pasture improvement.

Experiments show that nitrogenous manures encourage a greatly increased production of leafy herbage of high protein content, a growing food comparable to our high protein concentrate rations; this rapidly growing grass is best utilized by controlled grazing, which, under the intensive system, involves considerable outlay for fencing into small fields and laying on water. But it has been shown that under this system with favourable climatic conditions the production of pastures has been doubled, and the income, in terms of monetary returns from milk produced, has been increased even up to 100 per cent.

The system would seem to be of value to the dairy industry, particularly in areas of high production and high land values, and for small holders.

The system may enable a farmer to restrict his acreage taken up by pasture, leaving more land for hay production or other crops.

Experience is showing that a modification of the "tight" Intensive System has a practical application under ordinary farm management. It has been demonstrated that nitrogen stimulates early growth, and with a late growing evergreen grass like perennial rye extends the grazing period in the autumn, so by the judicious application of nitrogen accompanied by phosphates and potash, because balanced manuring must be practised to secure best results, the grazing season can be extended at both ends, thereby lowering cost of production and feed bills. The difficulties to be met in the use of nitrogen on pasture are: (1) unfavourable weather, a dry season like 1929 in parts of England is fatal; (2) nitrogenous manure tends to depress clover, the free nitrogen gatherer, though with well managed grazing this effect is not so marked; (3) the difficulty of adjusting the numbers of stock carried on the farm in order to make full utilization of the grass, as it varies in production throughout the season and years.

Agronomists now Turning their Attention to Agrostology.

Since the 80's, and particularly after the rediscovery of Mendelism in 1900, the attention of scientific workers in crop improvement has been mainly focussed on cereals. This is quite natural because of the importance of wheat as a human food, and, like oats and barley, it is an attractive plant to work with, but now, since that field has been well explored and additional increments in yield and quality are difficult to secure, it is natural that administrations and scientific workers should turn their attention to grass and forage crop improvement and management; a field which offers even greater possibilities for increasing yields than did the cereals.

Establishment of the Welsh Plant Breeding Station.

With the establishment of the Welsh Plant Breeding Station at Aberystwyth, Wales, for herbage plants in 1919, came a distinct impetus to grassland investigations; its influence has been felt in all parts of the Empire. This liaison will be strengthened now that the Imperial Bureau of Plant Genetics (Herbage Plants) has been established at Aberystwyth.

The Bureau is already rendering invaluable service to workers by collating and extracting the relative literature of the world and distributing this information throughout the Empire.

The appointment of an Empire Agrostologist has been another important and fundamental step in the direction of unifying Empire endeavour. Many benefits will accrue from his efforts as Technical

Liaison Officer between the different countries of the Commonwealth. For instance, Canada can learn many points of technique and practice from Great Britain and New Zealand, etc., and *vice versa*.

This new impetus is due to the viewpoint, personality, and enthusiasm of the Director, Professor R. G. Stapledon, and his keen co-workers.

GROWTH OF PASTURE WORK IN EUROPE.

One of the early pioneers in the development of the intensive system of grassland management in Germany was Karl Schneider-Kleeberg, Nieder-Walluf a Rheim, who started preliminary experiments in 1895. The gradual evolution of the intensive system may be studied in his book "Fettweiden im Westerwald," published in 1904, and "Die Anlage von Dauerweiden" (1926). In 1905 a short course of lectures on grass cultivation was held which was important because of its influence in Germany and the Scandinavian countries.

An interesting and important phase of the educational work carried out some 20 years ago was the establishment of grass gardens for observation and identification at strategic points throughout the countryside.

The intensive system of grassland management by the application of artificials and nitrogen developed rapidly in Germany during the war, because it was impossible to import concentrates "kraftfutter" to any extent, and an attempt was made to make up the deficiency by forcing grass, a high protein concentrate. It was said "that nitrogen was the cheapest 'kraftfutter'."

In the post-war period, during the inflation of the mark, it was difficult to import concentrates. Coincident with this Germany produced a surplus of nitrogenous manures and the price of nitrogen fell so that manuring of grasslands with nitrogenous manures was more and more employed to increase the production of fodder in pastures. It was during these periods that Professor Warmbold developed the so-called Hohenheim System of Intensive Grassland Management.

Another pioneer of the intensive system was Professor Falke of Leipzig University, whose first experiment on the intensive fertilization of pastures with potash, phosphoric acid, and nitrogen was laid down in 1899. Thirty-two enclosures were made on which eight different fertilizers were applied four times in succession.

On the basis of the findings of the above experiment a further experiment was laid down in 1904 in which the division of the stock into groups was particularly emphasised, i.e., first group comprising the high-producing milk cows, followed by second group of dry cows, etc. Young cattle were also divided according to age, nitrogen fertilizer being applied during the grazing period as circumstances seemed to indicate.

In the same year, 1904, Professor Falke arranged the first experimental pastures in the Free State of Saxony on Pfaffengrün, the estate of Count Feustel. A pasture was divided into five divisions, stock divided into a first group, bullocks, followed by heifers. The fields have been refertilized regularly, and these pastures may be inspected to-day after 26 years of such treatment.

Following this work co-operative pasture improvement associations have been formed, and the system has been steadily extending throughout the Free State of Saxony and the neighbouring States.

As Chairman of the Committee for Pasture and Meadows of the German Agricultural Association, Professor Falke was enabled to extend greatly the work throughout Germany even before the world war.

It is notable that throughout Europe and the Scandinavian countries there are special government departments and officers appointed to pasture investigations, a point in organization which might well be emulated and given greater emphasis throughout the British Empire.

The particulars of Dr. Falke's views may be found in his book on permanent pastures "Die Dauerweiden," a new edition of which is expected in 1931.

The experiment station of the Swiss Government at Oerlikon has long been celebrated for its tests concerning pasture problems.

The school of Schröter, Stebler, and Volkart have made a lasting contribution to the study of grasses because of their critical fundamental approach to the problems.

Of special interest are Professor Volkart's experiments and technique for studying survival and competition of species in pasture and meadow mixtures in different soil and climatic conditions; the results of the comparative yield and botanical analyses of survival over a long period of years are rendered in graphs. As a result of these

critical studies Professor Volkart classes grasses and clovers in two categories. The first contains species the development of which culminates during the first or second year, i.e., Italian rye-grass, timothy, meadow fescue, red clover, and alsike. The second contains species which reach their full development only in their third or fourth year, i.e., cocksfoot, yellow oat, smooth-stalked meadow grass, and red fescue.

Data gleaned by such a critical method in any region form a sound basis for compounding mixtures.

Switzerland is particularly rich in experience with the application of liquid manure to grassland, and the problems which arise from a long continued practice of this kind.

In Sweden, Dr. A. Elofson, Director of the Swedish Meadow and Pasture Improvement Association at Upsala, has for many years worked most enthusiastically for a more economical production of hay and pasture crops, and has been a close student of the agriculture of the continent.

The Swedish Pasture and Meadow Association was founded in 1916 through the initiative of Dr. Elofson and several prominent estate owners who had co-operated in the pioneer work for pasture improvement.

Through a working arrangement with the Forestry Department much of the unproductive marginal land where pastures merge into the forest has been cleared and made into highly productive pastures.

Much experimental work has been carried out on the effect of different manures which has shown the undoubted value of phosphorus on Swedish pasture flora. Experiments are being conducted on the intensive nitrogen system, botanical association studies, cutting *versus* grazing, cutting at different stages of growth, and the management of the grazing animals which are divided into three groups: (1) high production cows; (2) dries and young cattle, followed by (3) horses.

Dr. Giöbel (4) says: "There seems to be no effort on the part of the Swedish farmer which leads to so rapid and sure results as measures taken to improve his natural meadows and pastures; and, if drainage is sufficient, no particular measure will give better money returns than judicious manuring."

A very important feature of the Swedish work is that there has been a definite attempt to establish the value of pasture as a crop in comparison with other crops. Agriculturists and economists have

co-operated towards this goal and are able to say " that where a system of permanent pastures has been tried it has been found that grass yields, in terms of feeding* units, may be considerably higher from those than from temporary leys, and that, in addition, the cost of production in the former case is usually materially less than in the latter."

" The acreage of permanent pastures may, under average conditions, be increased with great economical advantage to constitute around 25 per cent. of the total area formerly under cultivation on a farm."

It is of primary importance in our pasture improvement work throughout the Empire that we begin to think and talk of pasture as a " crop " in comparative terms with other crops on the farm, and experiments and studies should be carried out to establish the data on which this comparison can be made, in terms which will easily enter the common parlance of technical workers and farmers alike.

The Scandinavian countries were particularly fortunate in this respect, in the adoption of the feeding unit as a basis of the comparative feeding value of crops. The work was first initiated in Denmark and to-day it is a common experience to hear farmers in Scandinavia speak of crops in terms of feeding units, which is most important to a fundamental understanding of the economy of crop production, and greatly facilitates the effective liaison between experimental stations and farmers.

It would be a step in the right direction if the agencies throughout the Empire concerned with pasture improvement would give serious consideration to the adoption of the Northern Food Unit in pasture work.

An important experiment is under way at the present time in Sweden in which three technical officers are permanently located on three different estates in order to establish the comparative economy of pasture as a " crop " in comparison with other crops on the estates.

In studying the pasture work in Denmark and the Scandinavian countries one is impressed with the spirit of self-help and initiative which pervades the farm community, as evidenced by the number of co-operative pasture improvement associations which have been formed in recent years.

* The Northern Feeding Unit is based on feeding value of 1 kilogram of barley.

This is a type of organization which could very well be developed in the British Commonwealth in pasture work. It is most effective because it enlists graziers in a co-operative effort which is more effective than issuing propaganda and extension service from a central government bureau.

The Swedish Association has an effective extension service; a great deal of detailed work has been done in preparing advisory literature and record books for farmers' use to record and calculate the value of different treatments. Demonstrations and short courses are held and three advisory counsellors are at the services of the members.

As this voluntary association grew it received the support of the State, and this year, 1930, the Swedish Institute for Pasture and Meadow Research, the first of its kind in the world, was formally opened at Ultuna during the meetings of the 2nd North and Middle European Grassland Congress. The next congress is to be held in Switzerland in 1933.

Thus one can trace the evolution of the grassland improvement movement in Europe, stretching as it does from Switzerland to Sweden and from Denmark to Finland, to the efforts of the early pioneers at the end of last century, gradually spreading through co-operative associations which were ultimately aided by the State; and now through the efforts of the General Congress a central bureau is to be established to aid and co-ordinate the work of the different countries.

Much of the work in Britain and the Empire has had its genesis in that of Europe and its inspiration in the kindly co-operation of the European workers.

The agrostology division of the Svalöf station is being strengthened.

In Finland progressive work is being done in breeding grasses and clovers, and Dr. Charpentier of Olkkala, State Director of Pasture Investigations, is carrying out extensive experiments on the renovation and management of pastures, reclaiming stump and lightly wooded areas.

In the Russian Bureau of Applied Botany at Leningrad, a very comprehensive programme on the genetics, cytology, breeding, and management of grasses and clovers is being carried out.

The Danish organization can serve as an example to other countries because here the Farmers' Co-operative Seed Growers' Association controls the breeding and investigational work, cleaning and distribution of the seed, so the grower is assured of pedigree strains of grasses for specific purposes, i.e., distinct pasture or hay types, and besides a successful seed export industry has been built up.

NEED FOR PEDIGREE STRAINS OF GRASSES, SEED CERTIFICATION AND CONTROL DISTRIBUTING ORGANIZATIONS.

The fundamental need for the improvement of the grasslands of the Empire is a definite policy of breeding pedigree strains of grasses adapted to the requirements of particular regions, the certification and control of the sale of these pedigree strains, similar to that which obtains in cereal husbandry; witness the work of the Canadian Seed Growers' Association, an organization which was founded by the late Dr. Robertson, and the various European Co-operative Seed Growers' Associations, notably that of Svalöf in Sweden.

The Danish and Swedish organizations have also demonstrated that such methods of breeding and distribution control are effective in grassland husbandry as demonstrated by the spread of Dr. Witte's improved strains of timothy, "Gloria" and "Primus," and the winter-hardy Victoria rye-grass in Sweden, the introduction of which made possible the cultivation of this premier pasture grass several hundred miles farther north; this same useful policy has been carried out in Denmark.

It only requires initiative and perseverance to organize the same effective organizations throughout the Empire.

The scheme for inspection and certification of genuine English wild white clover being carried out at present by the National Farmers' Union in co-operation with the Ministry of Agriculture and Fisheries is a splendid example of effort in this direction.

The inspection and certification of lucerne strains in Canada under the supervision of the Canadian Seed Growers' Association is another example of this type of control.

Such a policy is of primary importance to a successful grassland improvement programme. Each region must have pedigree strains, bred for its specific requirements, with an abundance of certified seed available.

Farmers, the Trade and Investigators must come to think in terms of pedigree strains instead of bulk lots of seed—drawn from different parts of the world—which are often not suitable to the local habitat on which they are grown.

It is apparent to all how foolhardy it would be for the Canadian wheat grower to use seed wheat from Italy—yet Italian red clover finds its way through in the Trade, and is killed out almost a total

loss in the first winter. Though the recent seed staining regulation has put a stop to this, i.e., by requiring seed from proven "danger zones" to be stained red at the port of entry.

Likewise how foolish it would be for a Welsh grazier to use a hay strain of cocksfoot from Europe in a pasture mixture when he could use Stapledon's indigenous leafy, persistent pasture strain. And yet we are perpetrating this sort of thing all the time; no industrial business could stand such a loss for even a twelve-month.

The following experiments carried out at Aberystwyth bear out the truth of the above statements (5):—

- (1) Comparisons of certain indigenous and commercial strains of grasses in pure plots; actual counts of tillers (6 in. by 6 in. mesh). Seeded May, 1925. Counts of tillers taken August, 1929.

	<i>Lowland centres.</i>	<i>Upland centres.</i>
	<i>Number of tillers per sq. ft.</i>	
Cocksfoot (pedigree) . . .	52.4	32.4
Cocksfoot (commercial) . . .	11.8	3.4
Perennial rye-grass (ind.) . . .	61.6	3.4
Perennial rye-grass (com.) . . .	17.6	2.0
Tall fescue (indigenous) . . .	101.2	7.4
Tall fescue (commercial) . . .	45.6	3.6

Each count shows the indigenous to be superior to commercial. Indigenous cocksfoot outstanding under the more exacting upland conditions.

- (2) Simple mixtures with cocksfoot as the dominant ingredient. Seeded in 1925, analysed August, 1929:—

	<i>Per cent. contribution of cocksfoot tillers to total tillers.</i>	<i>Per cent. ground covered by cocksfoot.</i>
Cocksfoot (pedigree) . . .	36	38.5
Cocksfoot (commercial indigenous) . . .	31	28.0
Cocksfoot (commercial indigenous) . . .	29	27.0
Cocksfoot (commercial) . . .	12	13.0

The advantage of indigenous strains of cocksfoot against commercial is further emphasized in these simple mixtures.

PLANT EXPLORATION AND INTRODUCTION NEEDED.

Much effective fruitful work could be done by pursuing a policy of systematic exploration throughout the world for strains and ecotypes of grasses and clovers suitable for different regions within the Empire, as well as a more co-ordinated knowledge of the possibilities of interchange of varieties already within the Empire.

For instance, there is no doubt that careful exploration of Scandinavia and Russia would yield strains and ecotypes valuable for the high rainfall and winter snow-covered areas of Eastern Canada. The writer was particularly impressed with the possibilities of this while studying the work in Sweden and Finland.

The geology, soils, climatic conditions, and flora of Scandinavia are very similar to those of Eastern Canada. The flora of the pastures are almost identical with those of Ontario and Quebec, consisting largely of *Phleum pratense*, *Poa pratensis*, *Trifolium repens*, *Festuca pratense*, *Dactylis glomerata*, *Agrostis*, and some *Lolium perenne* in the milder south. These plants have existed under the hard climatic conditions for many generations longer than they have in Canada, and consequently there have evolved many winter-hardy types of value for direct introduction to Eastern Canada or to be used as a source of parental breeding material.

Russia would undoubtedly yield drought-resistant strains of value to Western Canada, as was the case with cereals; witness the work of Carleton whose introduction of the drought-resistant durum wheats from the Steppes of Russia to the central great plains of America, and the introduction of the hardy winter wheats from Russia, derivatives of which are grown in the enormous winter-wheat area stretching from Kansas to Alberta.

The whole history of the successful cereal breeding in Canada is one of primary introductions from Europe and Russia.

In all the romantic history of these valuable introductions, the story of Red Fife wheat and its influence on the quality and production of wheat in the Empire must not be left untold; coming, as it did, a precious plant emigrant to Canada from the Baltics, it proved after years of careful testing in the field and in the oven to be a wheat of such all-round superiority that it was used as the important parent for hybridization by Dr. Saunders in Canada to produce new high quality early wheats, the introduction of which has been steadily pushing the potential wheat-producing area farther north in Canada and west in

the high plateau country towards the Rocky Mountains. Indeed, the hard spring wheats of the immense area of spring wheat production in Canada and United States of America are predominantly Fife in ancestry.

Sir Rowland Biffen used Fife from Canada to improve the quality of the wheat of England. Farrer used it in Australia to produce Federation, a variety which some authorities say made possible the growing of wheat in Australia, and to-day Fife is being used to breed wheats suitable for Colonial Africa. It would be difficult to estimate the wealth of influence that this chance plant emigrant from Europe to Canada has had on Empire wheat production. This influence is especially significant in that it indicates the importance of a more systematic organized effort in plant exploration and introduction work in the Empire, which might well have a logical beginning in the naturally developing field of Empire agrostology.

Indeed, the most drought-resistant economic grass grown in Western Canada to-day is awnless brome grass (*Bromus inermis*), an introduction made in the late 80's from Hungary, and developed by McKay of Indian Head, Saskatchewan. Further systematic exploration work of this kind, i.e., introducing drought-resistant and winter-hardy grasses and clovers to Western Canada, would be a step of fundamental importance in developing mixed farming, and stabilizing the agricultural industry of that great wheat-growing region.

This is only an example of the many possibilities there are for the Empire to benefit from plant exploration work.

BIOLOGICAL UNDERSTANDING OF PASTURES.

The science of ecology, the study of plants and animals in relation to their habitat, has been making marked progress in recent years, and the application of the principles of ecology to the study of grasslands has had a definite practical value in the fundamental understanding of the plant-animal complex of the pasture field.

In many respects the new ecological viewpoint is the most important advance in pasture studies, because it stimulates research, opens up the way to a fundamental study of the question, and is leading to the development of exact experimental technique and criteria.

At this point it would be interesting to contrast the study of a cereal crop with that of a pasture crop.

To produce a cereal crop it is usual to seed a single annual species which is only called upon to compete with intrusive weeds. When the unmolested plants reach maturity they are harvested by a machine which leaves a dry, dead stubble behind; the life cycle is over in one season.

A pasture mixture is laid down containing many species, mostly perennial in character, each with a different "aggressive potential" differing in mechanical devices for competition, root range, water requirement, light relations; each with a different genetic and physiological constitution, zenith period of production, varying in palatability and appeal to the different species of grazing animals. A very different complex, is it not, from that of the cereal crop?

An ecological viewpoint is stimulating to the research worker, because it is fundamental and dynamic, and for this reason it is leading to the development of a definite practical technique in this era of progress in grassland studies. For example, the technique for survival studies in meadows and pastures used by Dr. Volkart, Zurich, Switzerland, and Stapledon, Aberystwyth, Wales; Cockayne and Bruce Levy in New Zealand. Technique to estimate the production of pastures by movable quadrats developed by Director Elofson, Upsala, Sweden, and Dr. Charpentier, Olkkala, Finland.

The ecological viewpoint has been responsible for drawing attention by Stapledon to the biotic factor, i.e., the grazing animal in this study of plant-animal complex, perhaps the most important factor in pasture management.

Had this relation of the grazing animal to the succession of plants been thoroughly understood and practised in the early management of the vast dryland range lands of Canada, Australia, South Africa, and India, the great losses in the carrying capacity of these grasslands caused by overstocking would have been prevented.

In pastoral areas of low rainfall the indigenous grasses depend on reseeding to a great extent to maintain themselves in competition with other species of uneconomic plants; this is in contrast to the vegetation of humid areas which relies on vegetative reproduction to a greater extent, long creeping stems, stolons, etc. Heavy grazing is essential on this type of pasture to ensure maximum nutritive returns; not so in the dry areas of the Empire where the natural

climax cover is an open " bunch grass " formation which, when over-grazed and no provision for rotation and rest period are used in the management, rapidly deteriorates to a surface bare of valuable pasture grasses, and is quickly invaded by moss, sagebrush, cacti, and hard zerophytic plants of low pasture value.

Pioneer Investigations in Britain.

The splendid early work on pasture improvement by Somerville, Gilchrist, Middleton, Armstrong, Hall and Russell needs no enlargement here. The doctrine of " phosphates and wild white clover " still stands a sound practical and reliable means of improvement, and is the outstanding feature of pasture improvement work throughout the Scandinavian countries.

While in Denmark it was interesting when inspecting a good pasture of English rye-grass and wild white clover to hear my Danish friend remark, " we do not apply nitrogen unless there is about 30 per cent. of wild white clover present." The Danes believe in English rye-grass, smooth-stalked meadow grass, wild white clover, and slag treatment. I met this opinion in Germany also.

THE NUTRITIVE VALUE OF PASTURES.

The valuable work of Fagan and Jones, 1923 (6), on the chemical composition of individual species of grasses clarified thought on this aspect of pasture management, drawing attention to the high nutritive value of indigenous meadow foxtail, and the high protein and very high yield of cocksfoot which makes it valuable despite its high fibre content. The fairly high quality of crested dogstail and red fescue whose persistency and consistent though not high yield throughout the season recommend them.

The fact that the total protein produced by hay and aftermath is less than that given by a smaller yield of well managed pastures, and that the quality of " winter pasture " is characterized by a high percentage of dry matter rich in minerals and that the protein content increases rapidly with the approach of spring.

The further findings on the comparative nutritive value of leaf and stem which show that the leaf portion of the plant is distinctly richer than the stem, constitute knowledge of great practical value to the plant breeder and in pasture management.

Table giving the chemical composition of the stem and leaf of cocksfoot and perennial rye-grass cut at three-weekly intervals. (Advisory Bulletin No. 2.)

Date of cutting .	Cocksfoot, 30/5/22.		Perennial rye-grass, 27/6/22.	
	Stem.	Leaf.	Stem.	Leaf.
Crude protein	17·70	35·19	11·68	18·87
True protein	13·09	29·41	9·37	15·18
Fibre	31·32	17·32	30·20	24·20
Ash	9·07	12·32	6·55	9·00

Table giving the chemical composition of four monthly cuts of perennial rye-grass and for comparison that of its hay.

Date of cutting.	Pasture cuts.		Hay cuts.	Pasture cuts.	
	5/5/22.	5/6/22.	16/6/22.	13/7/22.	31/7/22.
Crude protein	12·75	9·44	5·31	12·87	13·75
True protein	9·25	7·94	4·00	8·81	9·75
Fibre	18·05	27·04	30·02	25·55	27·15
Ash	11·25	6·72	4·75	12·95	11·80

It will be noticed that the composition of the pasture cut on June 5th more closely resembles that of the hay cut on June 16th, as Fagan says, "this to a large extent is due to the fact that at this date the pasture contains a higher proportion of stem. It will be recalled that at this time of the year the majority of pastures are stemmy in character."

Nutritive Value and Digestibility of Pasture.

Early work on the nutritive value of grasses has been largely focussed on the plants in the more mature meadow stage, data on the nutritive value and particularly the *digestibility* of pasture was not available in Britain until the late Professor T. B. Wood and Dr. H. E. Woodman and co-workers of the Animal Nutrition Institute, Cambridge, carried out their now well-known digestion work on grass in the pasture stage of growth.

This work marked a distinct advance in the fundamental understanding of the food value of pasture and is basic to a knowledge of intelligent pasture management and feeding of stock on pasture.

It was shown that grass in the pasture stage is a food with a protein content comparable to that of a concentrate like oil cake, and ample for the protein requirements of all classes of farm animals, so that on the basis of these findings the old practice of feeding oil cake on pasture is shown to be wasteful from a nutritional standpoint, and that if supplementary food is needed on pasture it should be given in the form of carbohydrate-rich food which will balance the ration, a new practice which is sound and will save money.

It may be interesting to mention that this has also been the experience in Sweden during recent years.

There is another important aspect of this work in that it shows the value of a close liaison between workers in nutrition and those in agronomy, particularly those engaged in forage crop improvement work. Heretofore experiments with forage crops have all too often been reported giving only the data on chemical composition and yield in dry matter. It is essential that such work be carried through the digestion phase, and future experiments should be designed to carry this out.

Woodman's valuable work of 1925 and 1926 (7) drew attention to the very high food value and *digestibility* of well-grazed pasture, facts which hitherto had not been thoroughly understood though so fundamental to intelligent pasture management.

That pasture grass under good management contains a very high percentage of protein *throughout the whole season*, "a high protein concentrate" which compares favourably in *digestibility* with linseed cake, is illustrated in the following table:—

	<i>Pasture grass, Spring, 1925.</i>	<i>Medium meadow hay.</i>	<i>Linseed cake.</i>	<i>Undecor. cotton cake.</i>
Percentage digestibility	83.6	51.8	80.1	58.0
In 100 lb. of dry matter—				
lb. digestible protein . . .	22.5	5.4	28.1	18.8
lb. dig. organic matter . . .	75.6	48.5	75.5	54.5
lb. starch equivalent . . .	73.7	27.7	83.3	52.3

The high protein concentrate nature of well-grazed pasture is readily understood if the physiology of the plant is considered, it is a well-recognized fact that young growing vegetable tissue contains a high percentage of nitrogen, and so by close grazing management a new green high-protein crop is kept growing throughout the season.

An even more important point was brought out in these digestive trials which demonstrated the high digestibility of the fibrous constituent of the pasturage, which is digested to an extent almost equal to that of the carbohydrate fraction—while in meadow hay the fibre content was shown to have a much lower digestibility.

This interesting contrast in digestibility is made clear when the physiology of the grass plant is considered. In the new, fresh pasture grass the cell walls are thin, rich in carbohydrate and easily digested by a ruminant, having in fact a value, according to Kellner, equal to that of starch, while in the more mature hay plant lignification has been going on for some time, producing a high fibre lignocellulose content of low digestibility.

Reflection on these findings brings us to an important consideration on the management of our pasture and hay crops. The following table shows that in Woodman's 1925-26 experiments, though the dry matter produced under hay management is about double that produced by pasture, yet in terms of starch equivalent the yield is approximately the same, while the pasture crop produces about one-third more protein per acre.

	<i>lb. per acre.</i>			
	<i>Pasture.</i>		<i>Meadow.</i>	
	<i>1925.</i>	<i>1926.</i>	<i>1925.</i>	<i>1926.</i>
Dry matter	3,065	3,667	5,943	7,990
Starch equivalent	2,124	2,532	2,093	2,880
Digestible protein	614	754	406	465

It is seen then that a well-managed pasture crop produces more food per acre than does the same area under hay, and certainly at a much lower cost.

Yet pastures are often neglected, allowed to take "pot-luck." The above data indicate clearly that in our crop husbandry we would make a distinct advance if we expended more care on the pasture crop which produces an ideal food at much lower cost than any of our farm crops.

Conservation of Surplus Grass as Grass Cakes or Silage.

The discovery of the high protein concentrate character of pasture grass led to further experiments by the Animal Nutrition Institute, Cambridge, and Imperial Chemical Industries Ltd., on the possibilities of conserving surplus grass in the form of dried, pressed grass cakes to be used as a substitute for ordinary high protein concentrates such as the oil cakes.

It is obviously a matter of great practical importance, and would effect a great national saving if this home-grown concentrate, the surplus grass in the flush of the season, or grass forced by nitrogen treatment, could be preserved as a concentrate to take the place of the expensive imported cake. Or again in areas of the Empire subject to periodic drought, supplies of dried grass cake would form reserves to aid in carrying stock over these crucial periods, preventing actual loss of stock, and sacrificing herds and flocks at low prices by glutting markets.

The following experiments carried out at Cambridge determined that dried grass cake is comparable in digestibility and feeding value with freshly-cut grass and the ordinary oil cake concentrates, and that the drying process does not lower digestibility to any marked extent, indeed increases the digestibility of the ether extract.

Woodman; *et al.* (8) determined the digestion coefficients of kiln-dried grass by feeding sheep with the same technique which was employed in the digestion work with freshly-cut grass in the 1925-26 trials, with the following results :—

Summary of digestion coefficients of kiln-dried and of weekly-cut herbage fed in the fresh condition.

	<i>Kiln-dried grass.</i>	<i>Freshly-cut grass (mean of 1925-26 trials).</i>
	<i>Per cent.</i>	
Organic matter	79·4	79·3
Crude protein	78·2	81·5
Ether extract	73·7	57·2
Nitrogen-free extractives	80·4	80·3
Crude fibre	81·0	80·2

Actual feeding experiments were carried out at Cambridge with dairy cows to compare the feeding value of grass cake concentrate

with the usual cakes such as linseed cake, etc., and the grass cake proved to be a useful concentrate for dairy cows, as it did in a further experiment with beef cattle.

A good deal of practical and scientific work has been done on conserving grass as silage in Holland, and Dr. Brouwer of the Hoorn Experimental Station concludes (9), as a result of his experiments and observations, that silage made during favourable weather for making of the hay which was used for comparison, that 100 kg. of dry matter in the silage had about the same feeding value as 105 kg. dry matter in hay. While in hay which had been harvested in less favourable circumstances, this relation was 100 : 120.

The losses of dry matter in the silage heaps vary from 15 to 30 per cent. and of hay in favourable years about 14 per cent., in unfavourable hay years about 30 per cent.

ROTATIONAL GRAZING WITH HEAVY MANURING.

Although graziers in Great Britain and on the estates in Germany and elsewhere have long recognized the value of changing stock from field to field and giving pasture a short time to recuperate, it was not until the post-war years that we in Britain heard much of "the intensive rotational system of grassland management." The genesis of the system may be found directly in the German war-time effort to force pastures by intensive manuring with artificials and nitrogen, thereby producing a high protein food as a substitute for the previously imported concentrates. It was a natural sequel to the pioneer work in Germany referred to above, stimulated at this time by the cheaper supplies of nitrogenous manures made possible by the improved methods of making synthetic nitrogen.

Professor Warmbold of Hohenheim, Germany, combined the principles of rotation with intensive manuring of small fields over which stock divided into Leaders and Followers were rotated. Hence the name "Hohenheim system," and as such was introduced to Britain by Mr. Carroll of Imperial Chemical Industries Limited.

There are two cardinal points in the system, i.e., (a) balanced manuring, the practicability of which must be worked out in terms of £. s. d. for the local situation, and (b) controlled rotational grazing, which does not involve so much expense and is more a matter of management, making for clean, economical use of the herbage. The animals graze the pastures evenly when controlled and do not leave large patches practically untouched to become stemmy and useless,

which is a common sight in any large pasture field where the animals are allowed free range to pick and choose. Another most important point is that weeds are controlled much more effectively under rotational grazing. Weeds lower the production of pastures tremendously, and are a menace to the surrounding arable land.

The *regular harrowing and surface cultivation* spreads the droppings, removes dead litter, aerates the soil, so that the field presents a clean cultivated appearance, a *properly cared-for crop* producing a maximum amount of grass at the stage of highest nutritive value to be utilized by the grazing animals. It is a method which can be applied in pasture management throughout the Empire to great advantage.

Principle of Rotation.

The principle of rotation is sound as borne out by the following experiments at Aberystwyth (22), Cambridge and in Finland and the experience of practical graziers.

At Aberystwyth, Wales, three lots of lambs were rotated over three ranges, each of which was sub-divided into five paddocks. The grazing was arranged so that on one range the lambs were moved from plot to plot every week, thus giving each plot an interval of four weeks' rest—this is referred to as the "month" strip; the next as the "fortnight" strip, and lastly the "four-day" strip where the lambs were moved from plot to plot every day so that each plot had only four days' rest between consecutive grazings.

From the following data it is seen that the most frequent grazing resulted not only in a lower increase in live weight, but also in a lower carrying capacity.

<i>Resting period of sward.</i>	<i>Aberystwyth 1928 and 1929.</i>			
	<i>Gain in lb. live weight per acre.</i>		<i>Lamb days per acre.</i>	
	<i>1928.</i>	<i>1929.</i>	<i>1928.</i>	<i>1929.</i>
Month	183	175	1,557	1,865
Fortnight	166	167	1,355	1,700
Four days	133	132	1,225	1,695

This is a most interesting and valuable experiment in that it shows the value of rotational grazing which can now be recognized as a fundamental principle to be followed in successful pasture management. The reason being that from the physiological-botanical standpoint grass which is grazed too closely in the "four-day" strip is robbed of its vitality and is therefore not able to develop a good root

system or leafy surface for maximum photosynthetic action, whereas the plants in the "month" strip have a chance to develop a good root system and a large leaf surface and the plants on a given area are able to manufacture much more food material than on a comparative area of the "four-day" strip. The food nutrients are better balanced in the older grass provided it is not allowed to become lignified.

The animals satisfy their appetite quickly where there is plenty of grass on the "month" strip and lie down in contentment, a most important factor in profitable animal production.

The value of rotational grazing is still further substantiated by the convincing work of Dr. H. E. Woodman, Cambridge, by the experiment in which plots of pasture were cut by a lawn mower at weekly, fortnightly and three-weekly cuttings, giving the following yields.

<i>Period 13th April to beginning of October.</i>	<i>Dry matter per acre, lb., 1928.</i>
Weekly cutting	1,982
Fortnightly cutting	2,562
Three-weekly cutting	3,216

Dr. Woodman says " though the herbage obtained under the more lenient three-weekly system of cutting was somewhat less rich in digestible protein, it was nevertheless equal in respect of digestibility and nutritive value to grass grown under systems of weekly and fortnightly cutting. At the end of three weeks' unchecked growth, pasture grass still consists of non-lignified, highly-digestible tissue as at the end of a week's, or of a fortnight's growth. It was further demonstrated that the depressing influence of drought on the protein content and digestibility of pasture grass is much less marked under a system of three-weekly cutting than under the severer system of cutting every week."

The above data and statements further elucidate the principle that in pasture management the herbage must not be eaten down too closely, thus undermining the vitality of the plants so that the growth of roots and production of leaf is curtailed, resistance to drought is lowered; which brings to mind an interesting parallel, i.e., experiments carried out in Canada and United States of America on the effects of close cutting of grasses, clovers and lucerne on their winter-hardiness. These experiments have invariably shown that close grazing or cutting in the autumn leads to a high mortality of plants during the winter and spring.

Dr. Oakley of the Bureau of Plant Industry, Washington, has shown that close cutting of grass limits the root growth in proportion to the cutting, results which give further weight and significance to the above.

The value of rotational management in reclamation work is clearly demonstrated in the following interesting experiments carried out by Dr. C. A. G. Charpentier, State Director of Pasture Investigations for Finland (10).

A former hay field on Mustiala Farm in the parish of Taumela in South Finland was turned into a pasture by dividing it up into small fields so that the rotational system could be carried out. No artificial fertilizers were used, so the following data show clearly the improvement which is possible in the carrying capacity of a pasture just from proper rotational management :—

Table showing increments of fodder units as pasture improved under rotational grazing on Mustiala Farm, Taumela, South Finland.

In 1926 during period	1/6-20/9	..	1,763	fodder units per hectare
„ 1927	„ „ 1/6-29/9	..	2,037	„ „ „ „
„ 1928	„ „ 4/6-30/9	..	2,274	„ „ „ „

Table showing the effects of rotational grazing on improving the carrying capacity of a rough cleared bush pasture on Laalahti Farm, Tampere, Finland, without use of artificial fertilizers.

1925 during the period	20/5-12/8	..	445	fodder units per hectare
1926	„ „ „ 28/4-10/10	..	633	„ „ „ „
1927	„ „ „ 18/5-1/10	..	836	„ „ „ „

That there is a great opportunity for this method of reclamation on the marginal rough grazing hill lands of Great Britain is seen by examining the work of Mr. Stanley Bligh of Cilmerly Park, Builth Wells, in mid-Wales (11), who after 35 years of experience in reclaiming these rough bracken, gorse infested lands, says that on “over two million acres of Wales and the West of England increased employment of labour and increased production are economically possible by those who take the trouble to learn the appropriate technical methods.” “Many farmers, however, simply cannot appreciate the potential value of pasture land properly cared for. I submit that in many instances they are letting a great national asset run to waste.”

“Thirty-five years ago I took over some grassland and offered it *in small lots.*”

There was the key of success. The "small lots" led to efficient close, rotational management, the ecological control of the flora reclaiming marginal land and creating useful high production pastures.

It is signal that the same method has been successfully followed throughout the Scandinavian countries in reclaiming marginal woodland and rough stump lands with equal and even more striking financial returns. It is significant that we must have an ecological viewpoint and base our technique on ecological principles if we are to advance in our pasture improvement work.

There was a gradual evolution in Mr. Bligh's methods ; first destroying the rubbish, economical draining, fencing into small fields, close rotational grazing, application of lime and especially phosphates and later in co-operation with the Welsh Plant Breeding Station the finding of suitable seed mixtures ecologically adapted to the local habitat, for long duration leys.

Mr. Bligh says : " Experience has shown that under this method of improvement, the pasture has improved consistently over a long period, owing to the close and controlled grazing made possible by fencing."

The following financial statement of Glan-Irfon Farm is convincing. This farm, 229 acres in extent, was rented in 1896 for £144. It has now been cut up into seventeen fields, carefully managed and now rents for £421 5s. 0d.

The following is a summary of the financial position :—

	£	s.	d.	£	s.	d.
Gross rent, 1926				421	5	0
Original rent	144	0	0			
25 per cent. increase	36	0	0			
Tithe	20	0	0			
Rates	25	0	0			
Interest and sinking fund on improvements	50	0	0			
				<u>275</u>	<u>0</u>	<u>0</u>
Balance (profit)				146	5	0

Mr. Bligh says " as a generalization, rents have been raised from something under 4 per cent. to nearly 7 per cent. of the original land value where improvement has been carried out."

VALUE OF DEEP ROOTED LEGUMES.

In Eastern Canada a large proportion of the pasturage is derived from the temporary leys of the regular rotation, and since the extension of the area of temporary leys in Britain is being considered, especially in East Anglia a review of Canadian experience may be of value.

The most marked improvement in the pastures and meadows of Canada and U.S.A. in recent years has come with the increase in acreage under Lucerne and Sweet clover (*Melilotus alba*). The latter a biennial particularly useful in short rotations.

One of the first things a Canadian agriculturalist remarks when visiting the farms of England are the neatly built ricks, but on examining the stacks of hay he is surprised to find such a high proportion of grass to legumes, and to note what an enormous amount of almost pure grass hay is fed to cattle including young stock and dairy cows.

It is true one finds splendid mixed hay of red clover and grass and luxuriant fields of red clover, but one notices comparatively few fields of Lucerne and to find a field where Sweet clover is being tried is like looking for a needle in a haystack.

Again one notices the tendency to buy in nitrogen on the farms in the form of protein concentrates and nitrogenous fertilizers.

Could not this outlay be curtailed by growing more Lucerne and trying to introduce Sweet clover, both high protein foods and free nitrogen gatherers?

The Canadian farmer effects a great saving in feed and fertilizer bills by growing these two high yielding, deep rooted legumes, they are considered to be essential in the rotation of any successful dairy farm. The colloquial saying is: "Grow your nitrogen on the farm instead of buying it."

The successful extension of the lucerne acreage followed the breeding of winter hardy variegated strains, i.e., Grimm and Ontario Variegated. With the production of a sufficient supply of home-grown hardy seed at reasonable prices and the improvement of methods of cultivation the acreage has been steadily increasing.

Sweet clover (*Melilotus alba*), which twenty-five years ago was a thrifty roadside weed, has been improved and brought into use over millions of acres in Canada and U.S.A., primarily as a pasture crop, secondly as a green manuring crop. It has proven useful in opening up heavy clays and building up light sandy soils, and of recent years is being successfully used as a silage crop, even in maize growing areas.

It is highly productive as a pasture, and being deep rooted is a drought resistant crop, and as such has proven valuable to supplement the grass pastures in dry seasons.

In comparison with a grass pasture which is shallow rooted, subject to drought, and a low nitrogen gatherer, these deep rooted legumes are very drought resistant, penetrating into the subsoil, utilizing, as it were, the unexploited reserves of the 2nd, 3rd, 4th, and 5th "farm" down, bringing up the valuable minerals. They fix free nitrogen, and give heavy yields of a high protein food.

Millions of acres of the shallow rooting grasslands of Great Britain and the Empire can be improved by the extension of these deep rooted legumes.

MINERALS IN PASTURES.

One of the most striking and fundamental advances in our knowledge of pasture-management has come with the extensive work which is going on throughout the Empire on the nutritive value of pastures, particularly on mineral deficiencies. It has focussed attention on *the geographical variation in the nutritive value of pastures*, leading in some cases to malnutrition and fatal pathological conditions.

The problem is basic—of all the means at our disposal for increasing the production of our pasture, balanced manuring is one of the most important.

Before a pasture improvement programme is undertaken in any area a "nutritive value survey" might profitably be initiated either by chemical analyses of representative "plucked" flora, or preferably by "area experiments" with actual grazing animals, in this way a zonal map can be constructed on which to base future manurial and floristic trials.

In early nutritional work calories and the "protein ratio" have been emphasized in computing the values of foods. Recent work has shown the importance of the mineral constituents, and in pasture management have long been recognized by graziers in an empirical way. In recent years these problems arising in animal nutrition from mineral deficiencies in pastures have been subjects of critical experiment, which have resulted in successful corrective measures being taken.

There is no need to dwell on the well-known early work of Armstrong (12) who showed that the better fattening pastures of Leicestershire were higher in nitrogen and phosphate, or the classical experiments of

Somerville (13), and Gilchrist (14), which demonstrated the benefits which may accrue, and the increased meat producing capacity of pastures due to the application of basic slag.

Theiler's work (5) in the Union of South Africa has shown that the low phosphorous content of the pastures is a limiting factor in the growth of young animals and in the milk yield of cows.

Aston (16) has shown that deficiency of iron is the cause of malnutrition in districts in the North Island of New Zealand.

In the Falkland Islands, Munro (17) drew attention to the high mortality of sheep, i.e. :

Lambs born 90 per cent.
 Remaining at dipping 52 " "

Major Walter Elliot focussed attention on the problem of malnutrition on the hill pastures of the West of Scotland, particularly on the "unsound" areas of Argyllshire, with the result that the committee of Elliot, Orr, and Wood initiated a survey of the pastures of Britain. "Plucked samples" were taken of representative cultivated lowland and hill pastures, and the analyses show (Godden (18)) that, though there is little difference between the caloric values of the hill and lowland pastures, the cultivated and lowland pastures are markedly higher in the useful mineral constituents, and further that the silica-free ash in the "not eaten" grass from the hill pastures is only approximately 50 per cent. of that in the "eaten" grass.

Fagan's work shows that similar mineral deficiencies obtain in the hill pastures of Wales as compared with the lowland pastures.

The following table gives some very significant data bearing on the chemical variations of pastures (18):—

	CaO	P ₂ O ₅	Na ₂ O	K ₂ O	Cl	N
	%	%	%	%	%	%
Island of Lewes—						
Eaten	0.286	0.243	0.377	0.678	0.115	1.340
Not Eaten	0.295	0.177	0.379	0.540	0.102	1.029
Falkland Islands	0.225	0.488	0.290	1.980	0.580	1.650
Lord Astor's race-horse pastures (highly treated)	2.473	0.997	0.698	2.398	0.498	3.562
Average for cultivated pastures	1.004	0.735	0.246	3.177	0.950	2.830

Another important question in the study of the nutritive value of pastures had to be answered, i.e., what is the seasonal variation in the mineral content of pastures.

Cruickshank (19) working on Aberdeenshire pastures at the Rowett Institute showed there was a definite seasonal variation, especially of the CaO, which rises to a maximum and then steadily falls, as do the P_2O_5 and Na_2O and silica-free ash, only to a less marked extent. The work of Woodman at Cambridge, and Fagan and Jones (20) in Wales show similar seasonal trends—points of fundamental importance to the practical grazier.

Critical experiments were needed on the effects of fertilizers on the mineral content of pastures. Godden (21) forthwith laid down experiments on red clover, temporary pasture and moorland pasture to elucidate this point, and found that by applying artificials to grassland the calcium, potassium, and phosphorus content could be altered and raised in a beneficial way.

Fagan (22), working on the effects of artificials on the hill and lowland pastures of Wales, concludes that by applying phosphates and potash there is an increase in the average percentage of these constituents as well as lime in the herbage, though no lime was applied. There was also an increase in the nitrogen content following the application of minerals—though the effect of applying nitrogen in addition to phosphates and potash has been to depress the average percentage of phosphoric acid and lime in the herbage.

These experiments mark a fundamental advance in pasture management. In the light of this work we now look on pasture as a growing food crop which can be altered in composition to some degree to meet the metabolic needs of the growing animal; critical deficiencies, which act as limiting factors, and sometimes even lethal, on the poorest pastures may be corrected by balanced manuring.

The "Pasture Animal Complex" is fundamentally a genetic ecological problem; we can govern the genetics of both our animals and plants and breed new and improved strains of both, but neither will reach the limit of their hereditary possibilities unless they are given balanced nutrition and suitable environment.

With such a fundamental understanding of the "pasture animal complex" it is possible to "grade up" the pastures of the Empire, as has been demonstrated in a practical way in various regions, to an increased carrying capacity from anything between 50 and 100 per cent., a practical possibility of no small economic importance to the British Commonwealth.

SPECIES IN RELATION TO GRAZING.

Recent pasture research points clearly to the fact that the grazing animal must be used as the final criterion in testing the value of strain or composite sward. By this method both the nutritive value and ecological reactions of the strain or mixture to grazing can be determined in a practical way comparable to actual field conditions which the old "measuring rods" failed to do.

This useful important technique is being rapidly developed at Aberystwyth by tethering pairs of sheep, and indications are that the tethering will replace the hurdle method. Recently cows and horses are being tested, because each species of animal has a different selective influence on the sward.

Species reaction to grazing is a matter of fundamental importance and demands searching study, especially in relation to the influence of growing stage and palatability.

Experiments conducted at Aberystwyth (20) on the differential palatability of grasses by actually observing the grazing animals ranging over plots of pure species gave the following results:—

<i>Species.</i>	<i>Percentage eaten in periods of an average of 24 hours of amount pure species offering.</i>
Timothy	49
Italian rye-grass	45
Meadow foxtail	33
Perennial rye-grass	32
Cocksfoot	32
Golden oat-grass	25
Red fescue	17

This experiment has a most important bearing on Eastern Canada in that it shows the high palatability of timothy, which is by far the most important cultivated grass in the great pastoral mixed farm areas of Ontario, Quebec, and the Maritime provinces, because it is winter hardy and suited to the soils and comparatively high rainfall of this region. The seed sown is entirely of the hay type; hence the introduction of a low growing, leafy pasture type of this palatable grass in the long leys and pasture mixtures will be of incalculable value.

The Differential Response of Species of Grass to Manures.

This is an extraordinarily interesting field of research in which there is still a great deal to be learned. It must be remembered that a large proportion of our pasture soils are of low fertility and carry a "sub-climax" flora of so-called "inferior" grasses and clovers, such as Bent, Red Fescue, Dogstail, Wild Red Clover, and Bird's Foot trefoil. These plants are persistent and are more or less in physiological equilibrium with the adverse habitat. It would be uneconomical to seed the "superior" grasses such as perennial rye or cocksfoot on such soils without creating a suitable habitat, by management and manuring, to hold them.

Fundamentally, then, to secure successful establishment and high production we must aim at a stage of equilibrium between plants, soil, and the grazing animals.

Experiments carried out at Aberystwyth (23) on the differential response of species to nitrogen reveal that this fertilizer increases production and palatability, lengthens the grazing season in the critical spring and autumn periods, and, further—a point which is particularly interesting and worthy of consideration—increases the production and palatability and therefore the consumption of a "long season" grass like red fescue, and the genetically early grass meadow foxtail. The economic significance of these findings is apparent.

Note the early date when these yields were taken.

<i>Species and Strain.</i>	<i>Air dry weights of pure species per 1/100 acre plot on March 26th.</i>	
	<i>With Nitrogen.</i>	<i>Without Nitrogen.</i>
Pedigree Indigenous Meadow Foxtail . . .	12.3	10.1
Commercial Meadow Foxtail . . .	2.1	0.7
Pedigree Indigenous Red Fescue . . .	20.5	15.0
Chewing's Red Fescue . . .	15.8	7.4
Pedigree Indigenous Cocksfoot . . .	9.3	9.0
Commercial Cocksfoot . . .	3.8	3.1
Timothy* (average of all strains) . . .	1.8	1.4

* A late grass.

The following table gives the percentage increase of yield of "nitrogenous" over "no nitrogen" plots for nine grazing dates, average of all species:—

May 3	34
May 25	57
June 22	57
July 13.	27
July 17.	35
August 17	45
September 22	60
November 8	92
March 26	55

Note the advantage gained by nitrogen in September and November.

There is evidence to show that there is a marked differential in the response of different species of grass to the various manures.

Richards of Rothamsted and Blackman of Jealott's Hill have interesting investigations under way, and the publication of their results will do much further to open up and elucidate this interesting and useful field of investigation.

TECHNIQUE OF GRASSLAND AGRONOMY.

One of the most valuable impressions a visitor to the Aberystwyth station receives is from a study of methods of carrying out tests and experiments in grassland agronomy.

Pasture and hay mixtures and new strains are tested out by seeding series of plots on farms covering a wide range of soil, climatic and grazing conditions, in fields where the farmers are laying down a new seeding, so that a direct comparison is made with the mixture used by the farmer. This method has a high demonstration value, as the data collected by officers from the station reflect the performance of the trials under actual farming conditions, and thus gains the confidence of the community.

It is apparent that this method has many advantages over confining the trials to the station; this is particularly true with grassland work. Manorial trials are carried out in much the same manner. Typical old pastures are chosen throughout the counties on which small areas are fenced. Within these enclosures experiments are laid down to test the influence of differential manuring on yield, chemical and botanical composition.

Here again local demonstration is secured, and, further, there is such a wide difference in the response of various soil types and their indigenous floras to manures, that local experiments are essential for the results to have immediate practical economic application.

Ecological experiments to test out the adaptation of a large range of grasses and legumes including improved strains are located in a wide range of habitats in hill and lowland centres.

Experiments on the effects of different intensities of grazing on various herbage associations are in progress. These are carried out by fencing off areas and using sheep as the "defoliating machines." The sheep are transported from centre to centre by lorry.

This policy of decentralization of experiments is particularly useful and essential in any comprehensive grassland improvement programme.

RECENT BREEDING WORK.

Early efforts on improvement of crops by breeding were focussed on the self-fertile cereals because apparently they offered the easier material to work with. In recent years attention has turned to improvement work on the open-fertilized crop plants, including maize, sunflowers, grasses, and clovers. Patient research has revealed that, in the group of open-fertilized crop plants, the possibilities of developing improved strains of practical value are even greater than was the case with the self-fertile group. Doubting Thomases are still to be found among technical workers, but we wager that, with the accumulating technical knowledge and improved methods of handling these open-fertilized plants, the next decade will witness a very large economic benefit from efforts in this field of plant breeding.

Everywhere one goes throughout Europe and the Scandinavian countries one is impressed with the work on breeding grasses and clovers and the interest taken in indigenous pasture strains.

There are three heads under which the study and improvement of pasture strains naturally fall.

(1) An *ecological* understanding of the behaviour and succession of the species under pasture conditions should be grasped.

(2) The *agronomic* value should be determined by investigating the characters, habits, quality, persistency, palatability, hardiness, and seed setting possibilities.

(3) *Genetic* studies and applied breeding and selective work.

Marked advances have been made in the breeding technique of clovers and grasses by Stapledon, Williams, and Jenkin at the Welsh Plant Breeding Station. Exact genetical studies have been under-

taken in this hitherto almost untouched material with most interesting and valuable results. The technique of crossing has been greatly improved so that it is now possible to carry out extensive hybridization with parents of known genetical constitution, which is a distinctly improved method which can be carried out parallel with the old method of mass selection.

At Aberystwyth extensive nationality and strain trials established the superiority of certain ecological place types, i.e., Montgomery clover, indigenous wild white clover, indigenous cocksfoot, ryegrass, etc., and pointed the way to improvement by selection and breeding.

One of the most striking and important results has been the recognition of the *superiority of indigenous over the ordinary cultivated grasses and clovers for pasture purposes.*

These interesting results are readily understood when analyzed with a genetic physiological viewpoint, *the low growing, persistent, leafy, nutritious plants or ecotypes* found in the old pasture fields are descendants of lines which have been subject to perhaps hundreds of years of selection in the pasture habitat under grazing conditions, and so are genetically and physiologically more or less in equilibrium with the requirements of a pasture habitat, producing a *high proportion of leaf to stem*, often physiologically adapted to soils of low fertility, and usually poor seeders, whereas in contrast the commercial or "cultivated" strains have been selected by man very largely for hay and seed production, and this process of *artificial selection has tended to isolate stemmy, low leaf, prolific seed bearing plants of poor pasture value.*

The marked superiority of these indigenous strains developed at Aberystwyth in pasture production has been amply demonstrated in critical field tests.

A good deal of experimental work has been carried out at Aberystwyth on methods of seed production, row cultivation, island isolation, and manurial trials, which have demonstrated the value of nitrogenous manures in forcing seed production, and the differential response of species to manures is being studied.

Considerable bulk lots of seed of a number of pedigree strains have been produced and are ready for multiplication and distribution to farmers, an enviable record for a station only ten years old. The era of pedigree strains of indigenous grasses and clovers has commenced—a milestone marking another distinct advance in pasture management and the application of science to agriculture.

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It is with pleasure that I think of the cordial reception accorded me by Continental workers, and I thank most heartily the Directors and Staffs of the Research Stations whose work I have studied in Switzerland, France, Germany, Austria, Denmark, Norway, Sweden, Finland, and Russia.

O. McCONKEY,

November, 1930.

Christ's College, Cambridge.

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