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COMMONWEALTH OF AUSTRALIA

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AGRICULTURAL RESEARCH

IN AUSTRALIA

Being a

Report of the Proceedings at a Conference of Agricultural Scientists held in Melbourne, 9th to 16th November, 1917

Published under the authority of

THE EXECUTIVE COMMITTEE

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H. T. EASTERBY, General Superintendent, Bureau of Sugar Experiment Stations, Queensland.

T. THOMPSON FLYNN, B.Sc., Professor of Biology in the University of Tasmania.

W. HEBER GREEN, D.Sc., Lecturer in Agricultural Chemistry in the University of Melbourne.

W. RUSSELL GRIMWADE, B.Sc., Messrs. Felton, Grimwade and Co., Melbourne.

T. HOGG, Managing Director of J. Miller and Co. Pty. Ltd., Melbourne.

D. MCALPINE, formerly Mycologist to the Department of Agriculture, Victoria.

J. W. PATERSON, B.Sc., Ph.D., Professor of Agriculture in the University of Western Australia.

J. T. PRIDHAM, Plant Breeder, Department of Agriculture, New South Wales.

H. PYE, Cerealist to the Government of Victoria.

H. C. QUODLING, Director of Agriculture, Queensland.

A. E. V. RICHARDSON, M.A., B.Sc., Agricultural Superintendent, Victoria.

TEMPLE A. J. SMITH, Closer Settlement Board, Victoria.

G. L. SUTTON, Agricultural Commissioner for the Wheat Belt, Western Australia.

R. D. WATT, M.A., B.Sc., Professor of Agriculture in the University of Sydney.

H. WENHOLZ, B.Sc. (Agr.), Inspector of Agriculture, New South Wales.

W. B. ALEXANDER, M.A. (Secretary).

GROUP OF MEMBERS OF THE CONFERENCE. *Photo. by "The Leader," Melbourne.*

Back row (left to right): W. B. Alexander (Sec.), Prof. T. T. Flynn (Tas.), G. L. Sutton (W.A.), Dr. W. H. Green (Vic.), A. E. V. Richardson (Vic.), H. T. Easterby (Q'lnd.), D. McAlpine (Vic.), H. C. Quodling (Q'lnd.), J. T. Pridham (N.S.W.).

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FIRST SESSION, 9th NOVEMBER, 1917.

OPENING ADDRESS.

Prof. D. Orme Masson, F.R.S., Deputy Chairman of the Advisory Council of Science and Industry, in opening the Conference, said :—

GENTLEMEN,

As you know, we hoped that the Prime Minister would be here to welcome you, and to open the proceedings of this Conference with an address. The Prime Minister, especially at this time, is a man on whose time and energy there are so many calls that of course it is never possible to be quite certain of his movements, but we know that he hoped very much to be present. In the event of his being unable to attend, we hoped that Senator Russell, another member of the Cabinet, would have been here to represent the Prime Minister, but you know there are special developments at this time in reference to conscription, and everything else must take a back seat to that issue. At this moment the Ministers are in Cabinet, and that was not expected a day or two ago, so that it devolves upon me at present to offer to you all a very hearty welcome, and I do so on behalf of the Government and on behalf of the Advisory Council, on whose advice this Conference has been called together.

I hope that both the Prime Minister and Senator Russell will be able to meet you. There is a chance that the Cabinet meeting will be over in time for them to do so at afternoon tea to-day, but in any case the Prime Minister sent a message that he hopes to meet the Conference before it finishes.

In the meantime, may I say a few words as to the origin, and what we hope will be the function, of this Conference ? Yo know that the Advisory Council of Science and Industry was instituted by the Commonwealth Government for the purpose of advising the Government on all questions in reference to scientific research, and especially on scientific questions in regard to Australian industries, and we have a very varied programme of work, for we are charged with looking after, to some extent, all the industries, including the primary and secondary industries. Now everybody knows that in Australia the primary industries are of paramount importance, and the Executive Committee of the Advisory Council has in the course of its work been more and more impressed with this fact, that the primary industries, especially the pastoral and agricultural industries, offer more pressing problems, problems that offer a bigger and perhaps more speedy promise of returns of value to Australia, than the secondary industries. I am not of course indicating, or attempting to indicate, that the secondary industries are unimportant, but undoubtedly more pressing and important problems are met with when one is dealing with primary industries, and particularly the pastoral and agricultural industries. Now, that being the case, it is of the utmost importance that the Advisory Council should have the best advice in connexion with agricultural scientific work, because it would be quite easy for the Advisory Council to do more harm than good. The fostering of agricultural industries is a State function, and as you know a great deal of valuable work has been done in the past, and is being done now, by the State Agricultural Departments and by the scientific experts who are officers of those Departments, and much work is going on in research farms and experimental stations under the guidance of these scientific experts. The question then arises—What room is there for any interference by the Federal body and what should be its functions in connexion with the further progress of agricultural work? Some might even suggest that it would be better to leave the States alone to manage their own business, but we have in view the United States of America where a very similar position exists. There we see that for some time past there has been a very active Federal Bureau of Agriculture, which has been working hand in hand with the State bodies and State officers, apparently without any friction, and with very admirable results. As you know, the Federal Bureau of Agriculture in America is a vast organization, spending vast sums, always augmenting and co-operating with the State Bureaux. It is possible, therefore, that in Australia some such body might be formed on similar lines. Both here in Victoria and in the course of our visits to other States we have been struck with this fact, that, while in some directions a great deal of valuable work is going on, the agricultural experts and experimenters suffer, and say so, from some lack of free communication on the subjects of their work with the men in other parts of Australia, who are working on the same or similar lines. It is perhaps a necessary failing in a vast country like Australia, but we gather that there does exist a constant danger of overlapping and less co-operation between workers in different parts of Australia than there might be. I am not putting this forward as a statement of my own, but rather as a statement based upon what we have been told by leading agricultural experts, some of whom are present to-day, and for this reason we saw that we ought to seek the best advice. It occurred to the Executive Committee that such a Conference as this, which is now meeting, would be an admirable first step, and we consulted the Ministers of Agriculture and officers of the State Departments, and in all cases approval of this idea was expressed. We hoped that this Conference would have met last year, but from various causes it was not possible. However, we are here now.

It follows, however, that the Executive hopes that this Conference will do two things—perhaps I should say three. You will consult with one another as to the past and present state of knowledge in respect of those important subjects which are on the programme. You will consult with one another as to the best future scheme of work and the best method of ensuring that that work shall be shared, and shared fairly, among the different workers of Australia. Thirdly, you will be able to offer to the Executive Committee some advice as to ways in which the Federal Government, operating through the Advisory Council, can help the progress of scientific agricultural research in Australia without producing harmful results by interference, but by helping the State activities and the work of all those who are engaged in such research. I need hardly say that all resolutions which are passed by the Conference and forwarded to the Executive Committee will receive the very fullest and most careful consideration. It may not be in the Committee's power to help in all the ways which you may suggest, as our financial powers are limited, but all the recommendations you make will be very carefully considered, and the Executive will be glad to call the attention of the Prime Minister and the Government to any practical steps which seem to be pointed to as the result of this Conference.

Prof. A. J. Perkins, Director of Agriculture of South Australia, was unanimously elected Chairman of the Conference. After a short discussion as to the procedure to be adopted at subsequent meetings the Conference adjourned.

Saturday, 10th November, was devoted to a visit to the State Research Farm at Werribee, by invitation of the Victorian Department of Agriculture. The members of the Conference were welcomed on arrival at Werribee by Dr. S. S. Cameron, Director of Agriculture of Victoria, and were conducted over the farm by Dr. Cameron and Mr. A. E. V. Richardson, Agricultural Superintendent. At the conclusion of the visit Prof. Perkins expressed the thanks of the visitors and their appreciation of the work being carried on.

SECOND SESSION, 12th NOVEMBER, 1917.

WHEAT BREEDING IN ITS INCIDENCE TO PRODUCTION.

By H. Pye, Cerealist, Victoria.

Many Australian farmers have been working on a low gear. This may seem sound philosophy, but it will not stand the strain the future will put on it. A speeding up is absolutely essential, and the farmer who will not recognise this must make room for the one who will. No occupation is of more moment to the Commonwealth than farming. The farmer will carry the main burden of the war.

Too much depends on the farmer for him to be satisfied with a restricted horizon. He must rise to the occasion and extend his vision over the plains of industrial and professional progress. The soil is the heirloom of the people. A permanent right to it is measured by the farmer's capacity to repay what is due to the nation. He must recognise this, since the people will not starve. The lessons learned from history prove that the decadence of farming led to the downfall of the greatest of past nations. Far-seeing statesmen know it, and foster the spirit of enterprise in the realms of agriculture.

Many farmers consider their occupation a closed borough; but, thank heaven their numbers are becoming fewer every day. They resent the intrusion of scientific research into their sphere, and carping critics add fuel to their ignorance. Mistakes are occasionally made in the name of science, but the record of splendid progress made by scientific workers vastly outweighs them.

The agricultural progress of the future will depend much on the co-operation of effort of the scientist and farmer. Great national changes and reforms loom in the near future. We cannot remain as we are. The world forces are irresistible. The farmer must move with them, and co-operate with others in guiding these forces. The days of the individualist are numbered, and those of organized communities are with us. The farmers, then, must move in the mass. Their strength lies in this. No nation can progress when community interests remain disorganized or are divided into antagonistic camps. The younger generation has views differing from those of the generation just past. Within the last few years the times have changed still more. The world has broken with the past. A mutation has suddenly sprung into being that has dominated the entity of every nation. Is it possible then for the old order of life to continue in the even tenor of its ways? The reply is obvious—it is impossible. Yet many will fight desperately against any change.

The great war has shown to what extent the internationalizing of industry and finance has developed with its attending dangers. The paralysis of trade is not yet felt in the Commonwealth to the extent it is in the older countries nearer the war zone. The Federal Government has taken a far-seeing and statesmanlike view of the situation in so far as industrial and agricultural progress are concerned by establishing the Advisory Council of Science and Industry. It should be the medium for crystallizing effort, a stimulus to invention and economy of effort, and a distinct influence in the establishing of new activities. The destiny of a nation should not be left to amateurs, nor should the progressive development of industry be left to statesmen without the authoritative advice of a body whose members should include the greatest practical-minded scientists and business men of known ability and standing in the respective industries.

The encouragement of new activities, especially the widening of the agricultural outlook of the Commonwealth by the greater development of the minor rural industries and the establishing of new ones, will absorb the energies of a percentage of repatriated soldiers, and pioneer the way for the rising generation.

The first step, as it appears to me, is to establish a Federal Bureau of Agriculture; then, federalize the scientific activities devoted to research. Organize the respective staffs according to their importance to the community, and make it worth while for University and other graduates to specialize in the more unpopular as well as the popular research work affecting the future progress of the Commonwealth.

It is not for a moment considered that the research work should be confined to a central Federal Laboratory, but some correlation should exist between it and the scientific staffs of public institutions and stations devoted to special activities.

The first stimulus should be given in the primary schools, and, by a course of evolution, the brighter and more constructive minds would emerge into the various channels of science into which their inclinations led them, encouraged by the assurance that adequate remuneration would be given to enable the successful graduates to live under befitting conditions.

We should know from personal observation what others are doing in other parts of the world. The literature of other countries dealing with their various activities serves a useful purpose, but personal touch with them serves an infinitely more useful one. Travelling scholarships should be awarded to those of our sons and daughters who have pluck, initiative, and trained minds; encouragement should also be given to those who influence the future of agriculture and to the rising experts to visit other countries and absorb useful knowledge in the interests of the producers. Personal touch is an impelling force in human nature. It unlocks the gates of reticence and suspicion, and is an incentive and stimulant to higher imaginative work and progressive effort; in short, it puts soul into the life work of the truly scientific and practical mind. A block of marble has all the potentialities of a beautiful statue in the hands of the gifted sculptor, and the one who sees what the world's geniuses have carved, has ideals higher than one, equally gifted, whose inspirations are gained from plaster casts. This not only applies to art, it applies to every human activity. Thus the expense the Government may incur by sending the right men to see the organization and methods of the scientific and other experts of another country is amply repaid, by fostering increased efficiency and production; and, no-less important, reducing material waste and misdirected energy; and, probably, opening up new channels of industry. The knowledge gained by personal observation would be more accurate and convincing than that obtained from books, and such information is worth all the expense involved.

The plant missionary who travels countries remote from beaten tracks needs consideration. America and other countries send him, so should Australia. It is not in keeping with the spirit of our people to allow other countries to carry out this work for them. It is a real business proposition to send our own men, since our soil and climatic conditions are, in general, so dissimilar from those of other countries. New forms of cereals, fodders, grasses, and other economic plants may prove invaluable in themselves, or for crossing purposes. Encouragement of the rural minor industries would be a source of wealth and independence to the Commonwealth. Here again the importance of knowledge gained by personal touch with other people, who have for generations been occupied in them, is very evident.

The interests of women should also be considered. Many are enthusiastic gardeners, and with the right training would revolutionize their status as world's workers. Their boundless enthusiasm as workers in the interests of our soldiers, their great sacrifices, and their relative increasing numbers, make it a national duty to give them better opportunities to take a greater share in developing the minor rural industries.

With the exception of the breeding and improvement of wheat and a few cereals, plant breeding is only glimmering on the agricultural horizon in this country, yet Australia is eminently suited for the development of a great seed exporting industry. The only drawback at present seems to be the dearth of skilled plant breeders and seed growers. The war will do much to infuse a greater independence of the Commonwealth from foreign countries in seed production. It is independent of them in regard to seed wheat, and this, I believe, is due in the main to the great impetus given to wheat breeding by the late Wm. Farrer and the work of the Rust in Wheat Conferences of from 20 to 25 years ago. In recent years younger wheat breeders have done good developmental work, as have some observant farmers. The Government of Victoria has taken some interest in wheat breeding and wheat improvement, and the amount expended has been repaid more than a thousand fold. The same would be the case if plant breeding generally were encouraged.

If the results of the work of the wheat breeders were problematic, a hasten-slowly policy could be understood, but actual success has proved that the work done has been of considerable benefit to Australia, vastly repaying the moderate expenditure. Until recently the work done in this direction has been due to private or semi-private initiative and to purely patriotic motives. It is too important to leave wholly to private initiative, and this has been recognised by statesmen.

If a wheat breeder could patent his creation of a prolific good-quality variety he would be in a position similar to the inventor who creates some useful invention; but this is not possible, hence his work is a national one, and it would prove sound economy and statesmanship to help him in every possible way.

In order to encourage systematic work in the making of new wheats, it is important to determine the classes of wheat desired in the various importing countries; and to secure the market for these to specialize in the classes that this country is best suited to produce, and so gain the highest commercial returns for the growers' labour. Again, in regard to home consumption, more definite knowledge of the relative quantities of weak and strong flour wheats required should be known. This will be of more importance in the future, when such industries as the manufacture of macaroni, vermicelli, spaghetti and pastes, breakfast foods, &c., are established. Perfection in making these depends largely on the nature of the wheat, or the blend from which the flour and meal used is milled. With data as to the relative needs of the Commonwealth for different classes of wheat and a knowledge of the areas best suited for the growing of particular classes, greater definiteness would be given to the work of wheat breeders, and it would be possible to grow in each locality a wheat specially suited to its particular climate and soil conditions.

In the near future a more systematic method of handling wheat commercially will be in vogue, and in the terminal elevators the classification of the wheat for commercial purposes will probably be carried out, thus districts famous for their hard, strong wheats with high gluten content and quality, will have their special elevators, and the best weak wheats will be consigned to others, and so on. This means economy of labour and economy of time.

The great object the wheat breeder has in mind is to implant in varieties what may be called the positive or desirable qualities, and eliminate the negative ones. He endeavours to implant such strong hereditary influence in a variety that it will reproduce progeny identical with itself. A new environment sometimes brings into activity dormant factors, hence what seem to be sports sometimes appear. Experience has proved that every country should have its own band of research workers and plant breeders. It should go further, it should create in the minds of the farmers an interest in seeking promising natural sports in their crops, and should impress them with the absolute necessity of seed selection for their particular districts.

Public men who have travelled in other countries frequently advocate that this or that variety should be imported and spread broadcast over the land. These men frequently have little conception of the work done in their own country in the interests of wheat growers. Farmers, wisely, rarely take their advice, or they would be landed in the Insolvency Court. In almost every instance the wheats recommended have been experimented with at the various State Farms and found wanting. Thus the famous British wheats such as Little Joss, Square Head Masker, Essex Conqueror, and a number of others are absolute failures over the greater part of the wheat belt, both in yielding capacity and rust resistance. The best Continental wheats are practically failures here. A few American wheats are more promising, but none are equal in yielding capacity to the best of our own. It is sufficient that the wheat breeder selects from them those that will be likely to implant in varieties designed for Australian conditions some useful character. When it comes to high strength, good quality gluten wheats, we have them equal or superior to those of any other country. We must work out our own problems in regard to the production of suitable varieties. There is no other road to success, and the importance of this is now fully realized by the Federal and State Governments.

The success of wheat production is of so vital importance to the Commonwealth that, in my opinion, there should be special scientific laboratories staffed by trained scientists who will devote their whole energies to research work among wheats and other cereals. These men should be specially trained for the work and adequately paid. The assistance of chemists, pathologists, and plant physiologists would be invaluable to the plant breeder. Personally I feel this need.

As regards the milling and baking tests of wheats the cordial co-operation of the Chief Chemist and the Departmental Miller has been stimulating and helpful in planning future effort. Help has also been received from other States, especially from Mr. Guthrie, the Chemist for Agriculture of New South Wales.

Associated with the work of wheat breeding is that of plant breeding generally. Recently I saw cablegrams and orders from an English firm for beans and vegetable seeds amounting in value to over £20,000. The size of the order seems enormous, when it is considered that it is practically a standing order from only one firm to another for two or three lines of vegetable seeds, of which Canadian Wonder Beans formed the bulk. It meant, too, that a large capital would be needed to accept many such orders.

Allowing for the abnormal conditions of the times, and the necessity of the supply of flesh-forming food to replace the meat scarcity with beans, I believe, when peace has been declared, the fine quality of the seed to be sent, compared with the samples received as standards, will insure a lasting commercial connexion. The sample of beans sent as a standard was much inferior to the worst in stock. It was kiln dried, and had immature or imperfectly ripened seeds through it; whereas the Victorian product was practically perfect, being well matured, considerably larger, and was a brighter and more even sample. This can be well understood with the climatic advantages Australia possesses; and, with its irrigation facilities, this country could raise an abundance of the finest seed. All that is needed are the growers who understand the business. The demand will surely come, especially when a Federal Agricultural Bureau is established, since it would be one of its first duties to learn the needs of other countries, their shortage of certain products, and their surplus of others. At present the farmers do not interest themselves sufficiently in such matters. If they did, they would appreciate more the value of statistics.

The war has been the means of making the worth of Australia known, not only for its splendid fighters at the front, but in the many phases of industry, which, most likely, would have been now well developed, had there been a crystallizing influence corresponding to the Advisory Council of Science and Industry; and, in respect to agriculture, the establishing of a Bureau of Agriculture would most probably have been the means, among other activities, of founding a larger seed export business; instead of which seed inferior to that which could be bred and grown here has for years been imported. Had there been more travelling scholarships, and had the officers of the Agricultural Department had better opportunities of getting into touch with those of other countries, it is most probable that there would have been to-day a higher development of the minor rural industries.

As I have already mentioned, the future progressive spirit in agriculture will in the first place depend on the stimulus given to the scholars of the primary and secondary schools of the Commonwealth. The encouragement in the country State schools of experimental work tending to create the scientific spirit in the scholars by keen and accurate observation, personal touch with the work, and systematic recording of results would give a great impetus. Success depends on the enthusiasm, the knowledge of human nature, and the inspiring influence of the supervisors.

Work in relation to wheat could be carried out on the lines recently inaugurated in the Goulburn Valley Inspectoral District by Mr. W. J. Gray, M.A., Inspector of Schools. The schools of the district are organized as follows :—

A Chief Supervisor is appointed with the right personality to rouse enthusiasm in the work, and, with the inspector's support, he impresses upon the teachers and scholars the fact that they are doing good educational work that will redound to their country's credit and progress. The Chief Supervisor has associated with him a number of Assistant Supervisors, who have assigned to them a group of schools within a practicable radius of their own schools. The teachers of these schools form a sub-association, with the Assistant Supervisor as chairman. The Assistant Supervisors have a greater insight into the work than the other teachers; and, in order to encourage them, facilities are given to visit the Werribee Research Farm and other stations. They are also given opportunities of attending special lectures at the University and elsewhere on such scientific work as will help them in their efforts. A conference of the whole of the teachers is held annually, or at such other times as may be deemed expedient. One series of experiments consists of testing the comparative yielding powers of promising new crossbred varieties compared with the standard ones, such as Federation, Yandilla King, and others. The plots are necessarily small, but, in the aggregate, they are many. They are accurately measured, and are enclosed in a wire netted building, into which sparrows and rabbits cannot enter to spoil the miniature harvest. The building is made portable, and is moved each season to a plot of well fallowed land. No doubt two of these structures will be erected in some of the schools to carry out rotation experiments. The cost of the buildings is paid for from money earned by the scholars and teachers, the proceeds of concerts and other entertainments. Thus the scholars have instilled into them self-reliance and self-help.

The experiments carried out are similar in every centre. Thus, though the experiments carried out in one school may have only local significance, the accumulated results from each series of experiments will have a wide significance, and a certain amount of generalizing may be done. Thus, if one of the new varieties tested returns high yields in 75 per cent. of the school plots, it will interest the farmers, and they will test the variety on a larger scale. The scholars become very interested, as the experiments are so closely associated with their parents' vocation. Included in the syllabus are such experiments as the testing of light and heavy dressing of seed, manurial tests, early and late sowing, various methods of pickling wheat for checking disease, prolificacy of varieties, pot experiments with the various kinds of soil under different conditions, &c. Possibly as a future development the cross-fertilizing of the more easily demonstrated plants will obtain, such as some of the vegetables, flowers, and wheat.

The principles of selection of seed from the best plants are also instilled in the minds of the scholars. Thus, those who have been given the incentive through this insight into experimental work would act as a leavening in creating the right spirit, not only in improving the right strains of wheat, but of the other cereals and other crop plants which may dominate the fields of the districts they live in.

The strength of the above experimental work lies in the fact that it is not an impossible syllabus; and it is intimately associated with the life-work of the parents of the scholars. Its main objective is to turn out observant men and women who can think for themselves, and have the impress of farmers-in-the-making implanted in them. These young farmers-in-the-making would undoubtedly appreciate the work of the scientists, and a number of them would be likely to take a pride in growing pure seed as a business.

Encourage the establishment of seed-growing by either founding district seed-growers associations or by widening the objective of the present agricultural societies in order that there would be some public spirit infused into the movement. Some agricultural societies now give prizes for the best crops. This is not sufficient, though helpful. What is needed most are farmers who specialize in pure-seed growing; and, to encourage them, official recognition should be given their seed, in order to give confidence to distant purchasers of it. Naturally this entails inspection; but when the vast importance of the industry to the Commonwealth is considered, the expense is a mere bagatelle compared with the wealth produced.

It is said that farmers are difficult to move, but few will deny that the almost universal acclaim given by farmers to wheat breeders is due to their confidence in them, earned by patient, disinterested effort that has succeeded in a great measure in increasing their wealth. The fact is that very few scientists and city people know the language of farmers. They are poor translators of their idioms, and appear not to have the faintest notion of their trials or aspirations.

I would suggest that important and well organized annual seed exhibitions be held just after harvest, not only for wheat, oats, and barley, but for all commercial seeds, including vegetables, flowers, medicinal, and grass and fodder seeds; and special prizes given for seeds the products of which would encourage the establishing of new industries or a greater variety of food products and fodder.

In respect to wheat exhibits at shows, it appears to me the intrinsic merits of the grain should be considered in conjunction with its being a suitable variety to encourage. The awarding of a first prize to a high-strength good wheat that gives an unprofitable return is misleading to growers generally, and to some very costly. If the price of such a wheat is commensurate with its quality it could be understood, but if yield be considered, the interest in raising the yielding capacity of high-strength wheats would gain an impetus.

The trend of special exhibitions will be to educate both the rural and urban communities, and stimulate plant breeding and seed selection among growers. Also, the public-spirited millers and others engaged in industries associated with seed products would be likely to support the movement by donating valuable prizes. The Seed Associations of Canada and the United States seem to have accomplished much in this direction.

The development of private seed farms throughout the Commonwealth would add untold wealth to the whole community. The cause of the degeneration of varieties, with its attending losses, is mainly due to too little attention being paid by wheat growers to the selection of seed. If among the more progressive growers a few in each district would work in touch with the State seed farms, the amount of pure seed used would be much increased; and this seed being true, and possessed of the fewest negative qualities, would give enhanced yields.

Another reason why old standard varieties are passing out is that they are being replaced by more prolific varieties of higher quality produced at experimental stations.

The widening scope of the wheat breeder is due to the need of producing varieties for specific purposes. It is possible for some growers to augment their returns by specializing in the growing of wheats for these purposes.

The problem of the world's wheat supply in its relation to the Commonwealth directs attention to the utilizing of the areas of low average rainfall. Here again the work of the wheat breeder has a wide scope in producing drought-resistant and rapidly-maturing varieties which can supply from every inch of rainfall a relatively large percentage of grain. Australia has a great advantage over some other countries in regard to these dry areas, in the fact that the rain falls during winter and spring, and not in summer, when rust would play havoc with the yields.

A point of some interest arises as to what will be the ultimate effect of using such varieties as *Triticum Hermonis*, which is not only self-fertilizing, but appears to be also fertilized by wind-borne pollen. Another point of interest will be provided by observations relative to those varieties that on crossing throw many "grass clump" progeny.

I do not know if the experience of my fellow wheat breeders is similar to mine, but in recent years I have noticed more natural crosses than formerly; in fact, a number of years ago I was under the impression from experiments carried out that natural crosses were non-existent, except in the case of injured florets. This observation is mentioned, since, should it prove correct, the degeneration of varieties from trueness to type is likely to be more apparent in future, and hence the need for seed selection on farms will be greater.

The cause of the increased number of natural crosses, as determined by my own observations, is centered in the pollination of the florets, or, rather, the non-pollination of them. In some seasons I have noticed that certain varieties bear little pollen, and diminished yields result. I have actually lost varieties which have borne so little pollen that only occasional seeds have been formed in fine looking ears, and ultimately the variety has failed to reproduce itself. Mr. Farrer had similar experiences. It is probable that factors other than frost have played a part in this phenomenon.

Bearing in mind that certain varieties of pears and strawberries do not produce sufficient pollen to fertilize more than a few of their own ovules, it may be suggested that these phenomena are due to the fact that all these plants, including wheat, are artificial productions. Wheat under normal conditions being self-fertilizing, it follows that a variety which has a poor pollination is liable to be intermittent in yielding capacity, being more readily influenced by the seasons. This was apparent in some districts last season, and I am inclined to believe that it will be so this season. Last season I emasculated a bearded wheat, and left it to wind or insect pollination. Nine seeds were harvested. Eight germinated, and of these six had bald ears and two bearded. In those instances where there is a scarcity of pollen, I believe there is a good deal more wind pollination. This happens when the pollen has been eaten by thrips, which are very plentiful during some seasons, and appear like a plague of locusts.

It occurred to me that profuse and scant pollen-bearing capacity may be a pair of the Mendelian characters in wheat which influence prolificacy. The difficulty in determining this factor in terms of the Mendelian proportion is obvious, as the exhibits are so small and the ripening of the anthers irregular.

Constitution or vital energy is another factor governing prolificacy. It may happen the grain will germinate well, but, from lack of vital energy, there is not a strong vigorous growth. This is more noticeable in slow germinating seed, and this again may be due to the deficiency of pollen, or to lack of vitality in it. By selection, improvement may be made by growing the plumpest seed from the best plants. I say this advisedly, since the best ears are often developed in the least prolific plants, there being two or three good ones and a number of secondary ones that do not reach the same level, and so cause loss in harvesting them.

Prolificacy is a relative quality. A prolific variety in England is not necessarily a prolific variety in Australia. Hence when the Mendelian characters are considered in their practical incidence, prolificacy is dependent on distinct segregation of characters suiting the environments.

The Factors influencing the Prolificacy of a Variety may be epitomized under the following Heads :—

(*a*) The inherent qualities as applied to the actual prolificacy of the ear ;
(*b*) The inherent qualities as applied to the practical harvesting of the highest percentage of grain ;
(*c*) Climatic conditions suiting the variety ;
(*d*) Favorable soil conditions as regards texture, moisture, and plant food.

The Qualities associated with Prolificacy in its relation to Inherency and economical Harvesting are :—

(*a*) A well developed root system ;
(*b*) Tillering capacity suitable to the climate and soil ;
(*c*) Strength and stiffness of the straw both in relation to harvesting and climatic influence ;
(*d*) Flag development suitable to the climate in which may be included the form and size of the stomata ;
(*e*) The relative toughness of the rachis and rachilla and the holding powers of the glumes ;
(*f*) The number of rows of spikelets per ear and the thinness yet firmness of texture of the glumes ;
(*g*) The number of fertile florets per spikelet with which may be associated the pollen-bearing capacity of the anthers;

(*h*) The form or shape of the ear in relation to wind pressure;
(*i*) The density, plumpness, and size of the grain ;
(*j*) The constitution or vitality of the grain in relation to its germinating capacity and hardiness in withstanding fluctuating temperatures ;
(*k*) The capacity in forming a unit of solid matter with a minimum amount of moisture ;
(*l*) The capacity of forming a maximum amount of grain relative to other solid matter ;
(*m*) Resistance to disease.

Prolificacy is an essential quality whether for a weak flour or a strong flour variety. Profit in wheat-growing is bound up in it. Higher profits are dependent on the combination of prolificacy and quality. The work of the wheat breeder lies in accomplishing this. His field is wide, since climatic and soil conditions vary.

We have arrived at a stage which demands greater perfection in what are usually considered by the layman as matters of minor consideration. It is on the multiplicity of these small developments that the extra millions of pounds sterling depend. I believe 30 per cent. or even more of the increase in yields is due to the introduction of better varieties and better seed by the experimental stations of the Commonwealth.

Greater wealth is dependent on improved methods of cultivation, more general appreciation of better rotations, a better knowledge of fertilizers, economical harvesting, and commercial handling of the grain.

Subsidiary to the production of varieties of grain for milling is the breeding of wheats rich in flesh, fat, and bone-forming constituents, and suitable for making good palatable hay. As wheat is practically the most hardy and drought-resistant of the cereals grown in the drier climates, special attention might well be paid to this last aspect. Here the services of the analytical chemist and the skilled feeder of live stock are needed. Varieties with suitable straw for plaiting would also prove of interest to the wheat breeder and to the straw hat manufacturer.

As each State must work out its own problems though a number are common to all States, it is evident that for practical and scientific comparison, methods should be standardized. This does not preclude original work for confirmatory or other purposes, but there should be standard methods in testing, in order that every variety may start on the level. More personal touch is needed among the band of scientific workers. Not only that, but some means should be adopted by which the practical and scientific-minded representative men of the industries dependent on cereals should meet together to discuss the problems from each others' point of view. Until this is accomplished, the real stimulating influence of the interested public, with its educational uplifting, will be lost.

The drawing up of an approximate soil survey of the possible wheat-growing areas of the Commonwealth, including those already under wheat cultivation, should be made in order that intelligent systematic research in wheat breeding and selection, as well as on cultural methods, may be carried out. This survey would at the present time only suggest the approximate limits of the various kinds of wheats likely to succeed ; but the experimental trials would give the wheat breeders information in selecting the types which should be used in the breeding of more prolific ones and those which have inherent in them drought resistance and rapid maturity in the more arid areas, and rust resistance and rust escaping qualities in those areas on the fringe of country too moist during the ripening period of wheat to escape the ravages of rust. Even in the present wheat-growing areas the wealth lost last season in a number of districts by rust amounted to hundreds of thousands of pounds sterling, since the varieties commonly grown are not rust-resistant.

With the advent of the higher development of the wheat industry and the establishment of elevators the classification of wheats will come into prominence, also the nomenclature of varieties will need consideration.

It will possibly be necessary or at least advisable to sell wheat under the name receiving official recognition, so that it may more readily be consigned to the elevator for its class. It will tend to reduce handling expenses, and it is in the direction of these that increased profits lie.

Twenty years ago wheat breeding was considered by many as a fad. The older wheat breeders who pioneered the work had little encouragement, but their persistence has been rewarded. The farmers were the first to grasp the importance of wheat breeding. To-day the whole community does so. Millions of pounds sterling have been added to the wealth of the Commonwealth through the researches of the wheat breeders and the voluntary workers associated with them. We must set our faces to the future, and co-operate more in the work before us, endeavouring by personal contact to achieve that driving force that stimulates and creates in a movement the right spirit.

Critics whose tongues are venom-tipped may appear, but workers' deeds outweigh mere words. The wheat growers' co-operation in the work is essential and we must convince them that the successes of the last 25 years are only the forerunners of greater ones, and that now is the time to prepare for the future.

Discussion of Mr. Pye's Paper.

Mr. Pridham commented on the interesting fact observed by Mr. Pye that some varieties of wheat produce a diminished quantity of pollen. He had not observed this.

Prof. Watt said that the Government of Victoria was to be congratulated on having liberated Mr. Pye from his other duties in order that he might devote the whole of his time and energy to the extremely important work of wheat breeding. Mr. Pye in his comprehensive paper had dealt with numerous important matters which would engage the attention of the Conference at a later stage, so he would confine his remarks to the subject of plant breeding. Like Mr. Pridham he was interested in the observations of Mr. Pye as to the diminution of pollen in certain varieties of wheat, a fact that was new to him, but which he would endeavour to observe in future work.

The question of prolificness which Mr. Pye had raised should form a valuable topic for the Conference to discuss, and he hoped members would express their views upon it. At Svalof, in Sweden, prolificness was considered to depend upon three factors, of which frost-resistance and rust-resistance were two. Mr. Pye had suggested some twelve factors which influenced prolificness in Australia. Obviously, if this view were accepted, it would be very difficult to breed wheats for prolificness. A measure of prolificness was a great desideratum.

Mr. Quodling referred to the position in Queensland, where only some 270,000 acres are under wheat, and last year 2½ million bushels were produced, which was insufficient for local requirements. In Queensland rust was much more serious than in the other States, owing to the warmer climate, and special varieties would have to be evolved to suit the special conditions. At present there was only one experimental farm (Roma), where wheat breeding was being carried on. Some of the wheats which had been under selection at that farm for seven years had given yields of 28 to 37½ bushels per acre, whilst the average for the district was only 7 or 8 bushels. Experience had shown that long-season varieties, heavy varieties, and flagging varieties were specially subject to rust, and on this ground they had had to be discarded in favour of short-season varieties with scant foliage and a good strong straw. He urged that plant breeders should meet annually in conference to discuss the problems with which they were engaged.

Mr. Richardson emphasized the importance of increased production as a means of helping to pay the war bill. He thought that attention had in the past been too much confined to wheat breeding, and that other crops should receive more attention from plant breeders, especially the most important of all our crops, the grass crop. The native grasses and fodder plants of Australia had not been valued as they should be. If the same amount of work had been devoted to them as had been devoted to wheat breeding, the continent would carry a great deal more stock than it did at present. He emphasized the harm that was sometimes done by political enthusiasts, who urged farmers to try some new variety which they had seen in other countries when travelling. Seeds of these varieties were often sold at high prices, and they had invariably proved failures, with the result that farmers were led to view all new varieties with suspicion. Some organization was required in Australia to deal with the introduction of plants from other countries, and make thorough tests as to their suitability for Australian conditions before they were put on the market. In this way much disappointment and loss would be avoided.

With reference to natural crosses, Mr. Richardson stated that in his experience at Werribee he had found that Indian wheats often crossed quite naturally and freely, and an undoubted natural cross had also been observed there in barleys. With reference to prolificness, he considered that it would not be possible to combine high quality and prolificness in the same variety, prolificness was obviously dependent on climatic conditions since varieties such as Cedar and Comeback, which were regarded as prolific in New South Wales, had not proved to be so in Victoria and South Australia.

At the present time, no encouragement is given to growers of good-quality wheats, as they get no advantage in price. In future, however, it seemed probable that wheat would be sold on a quality basis as it was in America, and this would be an inducement to growers to produce high-quality grain.

Prof. Paterson emphasized the importance of the work which Mr. Pye had accomplished. He had produced wheats which were in commercial favour with farmers, and he thought there must be immense satisfaction in such an achievement. He thought that the work of the Government farms where new varieties of wheats were produced should be continued by the encouragement of seed-farms where pure seed for the farmers should be grown. Special varieties of seed and special seed-farms might receive Government recognition. In reference to Mr. Pye's remarks as to agricultural experiments in primary schools, he contended that these were a mistake. The matter had been very fully considered in Western Australia, which he said without fear of contradiction was ahead of all the other States in the matter of agricultural education, and the conclusion had been arrived at that the experiments did not give results commensurate with the amount of time and energy they absorbed. The view adopted was that agricultural science should be included in the curriculum since all children would benefit by a knowledge of some portions of this subject whether they became farmers or not.

Mr. Sutton referred to the stimulus that the work of William Farrer and the Rust-in-Wheat Conference gave to wheat breeding a generation ago, and hoped that the present Conference would have an equally valuable effect in leading to the production of pure seed in large commercial quantities. He thought that the reason why the farmers had not taken up the production of this seed was on account of the great difficulty of keeping varieties pure. The difficulties in this direction in Western Australia were much greater than in New South Wales. He did not agree with Prof. Paterson's views on this subject, but thought that the State Farms should themselves produce pure seed for the farmers. With regard to agricultural experiments in schools, he pointed out that the majority of the teachers had not the knowledge or experience necessary to undertake them. He thought that by further work our most prolific wheats could be improved in strength. It was the farmer's business to grow varieties which filled the bags, and the wheat breeder should see to it that the varieties that filled the bags were also varieties which would make the best and biggest loaf. In Western Australia millers were urging the importance of growing strong wheats and were paying higher prices for these.

Mr. Pye, in replying, stated that he had a natural interest as a boy in crossing plants, especially potatoes. He started work on plant breeding from patriotic motives and he had received great inspiration from the work of his friend William Farrer. In spite of the opinions expressed by Prof. Paterson and Mr. Sutton, he thought that agricultural experiments in schools were of great value, they aroused interest not only in the children, but in their parents. He did not advocate very elaborate experiments, but thought that in country schools such work might well be substituted for the usual type of nature-study. He expressed his gratification for the appreciation that members had shown of the work he had been able to accomplish.

OAT AND BARLEY BREEDING.

By J. T. Pridham, Plant Breeder, New South Wales Department of Agriculture.

A.—Oats.

Oats in relation to Wheat and Sheep Farming.—Oats have ceased to be a crop only to be grown in cool districts of high rainfall, not adapted for wheat, they are necessary to the successful farmer on wheat country and in all mixed farming centres. It is impossible for a farmer to get the best results without the rotation of crops, and oats supply the most valuable fodder and grain crop under present conditions.

For feeding off or for use as hay or grain it is superior to legumes, both in point of bulk and ease of handling, and fills a most important place in regard to wheat diseases, such as Take All and Flag Smut, which are on the increase, and do not thrive on the oat plant. Farmers who use wheaten chaff for their working horses are only sowing their land with the spores of these diseases, so that oats are really indispensable to the progressive farmer even in the warmer districts.

Farmers who go in exclusively for wheat growing become forced to the conclusion that some form of rotation is needed, even where bare fallow and sheep are included. The one-crop farm is destined to become a thing of the past with the advent of closer settlement and immigration. We would emphasize, therefore, the value of the oat crop, both as food for stock (which are yearly increasing in value to such an extent that natural pasture is no longer sufficient), and also as a means of dealing with wheat diseases. The average farmer has little conception of the annual losses due to Take All and Flag Smut, which claim 25 per cent. of the crop of wheat. This is a general estimate, which is believed to be well within bounds.

Oats are more suited to a cool climate than wheat, but just as the range of country adapted for wheat has been extended into such regions as Alaska and Siberia by employing suitable varieties, so the oat crop can be grown in comparatively warm and dry districts when the right variety has been discovered. The Algerian oat is wonderfully elastic in its range, but under arid conditions the growth is sometimes too short to be dealt with satisfactorily with the reaper and binder.

The price of oats is always considerably less than that of wheat, and the demand is limited, but not so restricted as in the case of barley. The use of maize for horse feed in Sydney and especially in the coastal districts has contributed to this; but, in order to supply even the New South Wales demand for oats, large importations are made. This unnecessary expense is incurred because it is not generally known that a prime sample of feed oats can be produced locally. Tasmanian white oats are quoted considerably higher than Algerians in the market reports, but when farmers realize that a plump feed oat can be grown in almost any agricultural district of New South Wales with a yield equal to that of Algerian, and a sufficiently fine straw for hay purposes if so desired, importations will weaken, and Algerians will be more exclusively grown for hay.

The almost universal use of the harvester does not admit of the highest possible returns from oats. It is estimated that harvesters will not strip more than 50 bushels per acre however heavy the crop. Yields of 90 bushels per acre have been obtained by cutting and threshing. The chief oat-growing State of the Commonwealth is Victoria, it produces over 65 per cent. of the total oats grown; Tasmania, New South Wales, and South Australia come next in the order of importance. The yield per acre is highest in Tasmania and lowest in South Australia.

Breeding Experiments.—Although wheat is the most valuable cereal crop in Australia, it was thought that some improvement might be effected in oats, which, as we have said, are so largely imported into New South Wales. At the suggestion of Mr. R. W. Peacock, manager of the Bathurst Experiment Farm, the writer made a start with oat breeding in the spring of 1904 when acting as experimentalist at that farm. The white feed oat, Carter's Royal Cluster, was most favoured by the manager next to Algerian, and it was proposed to improve the grain of this variety which was not sufficiently plump to compare favorably with New Zealand or Tasmanian grown samples. Oats of the potato type, in common with all varieties of the white feed class, mature too late for our climates, and suffer from the heat of early summer.

Their straw is too coarse for fodder, and in case of a failure for grain it is often necessary to cut a crop for hay. They show a tendency to produce " pin kernels " or secondary flowers which produce no seed, and their foliage is rather too heavy and abundant. The late Mr. Farrer did not encourage the writer in this line of work, giving it as his opinion that the Algerian oat would be very hard to beat. The Algerian variety is " par excellence " a hay oat, and we have nothing in sight which surpasses it for this purpose. But, rightly or wrongly, horse-owners seem to prefer the plump white oats for feeding purposes to mix with wheaten chaff or other fodder, and in the warmer districts, especially, Algerians compare unfavorably with these in that they are inclined to be long, thin, and flat-sided. White Tartarian " side " oats used to be in favour for hay, but they are now only used to any extent in country districts. In the cooler districts their heavy-yielding qualities cause them to be highly esteemed among farmers. Produce merchants, however, object to them, for the chaff cut from Tartarians is not nearly so palatable to horses and is coarser, besides being more bulky and lighter in weight than Algerian chaff.

A cross was effected in 1904 between Algerian and Carter's Royal Cluster, the former being employed as the mother. As we have found in wheat breeding that reciprocal crosses behave similarly in subsequent generations, Algerian has been usually used as the mother variety. Its large, strong glumes are more easily handled than the short and more delicate glumes of the late-maturing feed oat. The F^2 generation seed was sown in 1906, aggregating 1,092 plants. There were great differences to be seen especially in the early stages of growth. Some of the young plants had coarse, broad leaves, while others were almost like rye grass in their fineness. There was great diversity in their extent of stooling, in foliage colour, and in habit of growth (erect or prostrate). Some of them on approaching maturity showed the pink or reddish colour towards the base of the stalk which is characteristic of Algerian oats. On counting it was found that 32·48 per cent. of the plants exhibited the reddish straw colour which showed conformity to the Mendelian ratio. There was a little difficulty in determining which plants showed the tint in question, as the shades merged a good deal. The grain produced by the F^2 plants was of varying shades of brown, except in the case of a few yielding yellow grain. None appeared to be distinctly white like the grain of the male parent. Had a larger number of seeds been obtained from the cross the white seed colour would no doubt have appeared. About three-quarters of the plants produced brown grain.

In 1905 the following crosses were made :—Wh. Ligowo x Algerian, Red Rust Proof x Big Four, Early Red Texas x Wh. Ligowo, Early Red Texas x Big Four, Algerian x Wh. Tartarian. In each case an oat of the Algerian type was crossed with a late maturing variety of the " tree " class, except the last in which Algerian was crossed with a " side " oat. The plants of the F^1 generation were mostly intermediate in character, and of pronounced vigour, as is usually the case with crossbreds before they settle down to the normal vigour of a stable existence. In subsequent generations from oat crossbreds of the " tree " or branching type no individuals of the " side " type were found. Two attempts were made to cross Avena fatua with the

Algerian variety, and on one occasion with Chinese skinless, but without success. Dr. Trabut states that Algerian is descended from A. sterilis, whereas the ordinary cultivated oat of Europe—the white feed oats—sprang from A. fatua. A cross was made between a " false wild oat " resembling A. fatua in its hairiness of grain and the horseshoe-shaped mark at the base and White Bonanza. The progeny had for the most part slender straw, a somewhat pale foliage, and the open thin head with branches inclined to droop, of the wild oat. No individuals of promise resulted from the cross, and this line was not pursued further. Of the different crosses made since starting work with oats none have yielded so many good strains as White Ligowo x Algerian. From this union sprang "Guyra," "Lachlan," and two or three other strains of merit which have not yet received names. The Svalof Seed Co., of Sweden, thus describe their new pedigreed strain of this oat, which originated with the late M. Vilmorin, of Paris :—" Valued for its particularly fine quality of grain, its high yield and fairly early ripening, the Ligowo oat has obtained wide distribution in many countries, and is still strongly to be recommended under suitable conditions. . . . . Spikelets are very often three-kerneled. The grain is very large, broad, and plump, particularly full, with remarkably developed awns. Straw of medium height, fairly fine, rather brittle." The importance of securing suitable foundation stocks in breeding is very evident. Very often many years are wasted in experimenting with varieties which in the end prove undesirable for mating. Much time was taken up in the earlier years of Farrer's work in determining the effect of certain sires or mothers upon their progeny. We seem to have been fortunate in our choice of White Ligowo as a parent.

Awnless and Hulless Oats.—Mr. J. Raum (Expt. Stn. Record, Feb., 1910, p. 138) says that :—" The presence of awns is an important character in oats, though much influenced by the rainfall. The weight of grain, hull, and kernel increased approximately 10 per cent. with the presence of awns." The most productive of our new varieties are provided with stout awns, which, of course, come off in threshing. No beneficial results have followed our use of skinless oats in cross breeding, and Dr. Saunders, of Canada, does not seem to have been any more successful. The naked oat is liable to injury, and does not germinate so well as hulled oats. For oatmeal and breakfast foods the hulls are easily removed after heating, and as the skinless oat is not such a good cropper as the hulled varieties it is not in demand even for the manufacturer.

Selection, desirable qualities in—

(1) High yield of grain.

(2) Moderate per cent. husk to kernel.

(3) Elimination of " pin " or empty seeds.

(4) Straw not coarse but strong.

(5) Early maturity.

Other qualities are resistance to disease, good length of straw for hay purposes, absence of shedding, a straight (not crinkled) neck, good flavour of grain and straw, a moderate degree of stooling.

In connexion with the last point the writer has in mind Farrer's aim in breeding in the case of wheat for a limited number of stools for our climate. Algerian oats stool a little too much for our conditions ; it is only in a favorable season that a really plump sample of grain is produced by this variety, though the yield is high. The yield of grain per plant is the deciding factor in selection for productiveness, but we find that this is usually associated with a compact head and erect branches, rather than a spreading type of head with drooping branches, as has been observed at the Svalof Breeding Station.

Method of Crossing Oats.—The work is best done before midday, preferably before breakfast, as the flowers will stand more handling before the heat of the day. The large outer flower is employed, the smaller one being cut off. The flowering glume is drawn aside, and the flower emasculated. The glumes are replaced, so that foreign pollen will not enter. Pollen from the plant designed for the sire is then introduced. It is sometimes no easy matter to find a flower on the spike just ready to flower having the anther sacs about to burst. As soon as good pollen is secured it is introduced without waiting until the pistil is receptive. If the flower emasculated is at such a stage that it would have flowered in the course of the day one is quite safe in cross-fertilizing it at once. After pollenizing, a thread of fine cotton is wound round the flower to keep the glumes closed. Flowers not worked upon are cut off, and a small tie is affixed to the head as a distinguishing mark. The parents of the cross are entered in the field book against the numbers of the plot. The date is recorded, and the crossed seeds are not harvested till quite ripe. When sowing seeds obtained by crossing a few seeds of the mother plant are sown in the next plot alongside for comparison.

Natural Crossbreds.—In 1909 the seeds of various oat varieties and crossbreds taken from Cowra were planted at the Longerenong College, Victoria. Selections from these were again sown at Longerenong in 1910, in which year striking variations occurred in the plots of Algerian oats. Among these stood out several plants with coarser awns than Algerian, very tall straw, white large grain, a limited number of stalks, and ripening remarkably early. It was at first thought that the seed had become mixed ; but even if this had occurred there were no plants in any of the rows of crossbreds in any way resembling these. This particular type had not been observed before. This variation, with a few individual exceptions, bred true in succeeding years, and in January, 1913, was named " Sunrise " oats, on account of its earliness. It has proved suitable for fodder and hay on the coast, also for early hay and grain in the hot inland districts ; but, being a rapid grower, the yield is only moderate, and it cannot be sown early in normal oat districts unless the precaution is taken of feeding it off. In 1915 a plot of Sunrise sown from a single plant showed variations, some of which were harvested separate'y, and are being further tested. Besides differing in foliage, these plants varied in colour of grain from pale yellow to pale brown, instead of being white or greyish white like the original type. Some of the new strains stool more and a few less than Sunrise. Natural crossbreds have not been found in America by F. M. Surface and Dr. Raymond Pearl, but Rimpau, in Germany, reports five among nineteen different varieties over a period of six years.

A remarkable plant was found in Chinese skinless oats at Cowra in 1913. It was fully out in ear before the rest of the plot showed signs of coming into head. The early stools bore heads on which the upper flowers were like the skinless oat—three to five flowers to a spikelet—while the lower flowers resembled those of Algerian—two flowers to a spikelet, with the stiff glumes normal to Algerian. The early stools had a darker foliage colour than the late ones, which bore flowers typical of the skinless oat. The straw, when the plant matured, was reddish, like that of Algerian. The seed, partly naked and partly black or dark-brown hulled, was sown in 1914, and individual plants each season since then; but the progeny continues to be quite variable—some wholly naked, some half and half, and some yielding only hulled seed. The latter germinated and yielded best. This oat has been crossed with the Dun oat and Ruakura, but no promising material has resulted hitherto.

One of the natural crossbreds of the Sunrise variation found in Algerian oats in Victoria in 1910 was sown in 1911, when an oat resembling A. fatua occurred in the progeny in which the Sunrise type predominated. Sown again in 1912 the Sunrise seed bred true, but the wild oat type split up remarkably; the plants varied in seed-colour, degree of awn, stoutness of straw, hairiness of grain (some thickly felted, others smooth). None of these types seemed to be of economic importance, and they were not persevered with.

The following oats have shown well-marked variations, Kelsall's, Black Bell, Ruakura, and Winter Turf. These, when sown, have bred true. The type from Black Bell has a very glaucous foliage, and may prove rust-resistant. The selection from Ruakura suits our conditions at Cowra and elsewhere better than the original type. It is taller, stools less, the straw is stronger than that of the parent variety.

Field Crop Selections.—Very little of this has been done ; a few types have been isolated from crops of Algerian oats, but our attention has been mostly confined to crossbreds. The Kelsall variety already referred to, believed to be a strain of Algerian or Argentine, with short slender straw, was received from a farmer of that name in Warracknabeal, Victoria. We have used it in crossing. It is a very productive grain yielder, the seed is slightly less plump than Algerian, but the shortness and weakness of its straw are drawbacks to its cultivation. It has yielded best at Wagga the last two seasons, and best at Cowra for the three years 1913 to 1915.

Climatic Variations.—The tint of the seed colour varies in some seasons, and tends to become paler in hot climates. Oats from a cooler district brought to a warm one grow taller and appear to be more vigorous than those used to the warmer climate, but do not yield more grain. Oats vary in the proportion of straw to grain from season to season, and in the per cent. husk to kernel.

The percentage of husk in oats has been determined for the more important varieties, and the new crossbreds bred here compare very favorably with Algerian in this respect. Guyra contains an average of 27·12 per cent. husk, and Sunrise 25·65 per cent., as against 31·03 per cent. for Algerian. White Ligowo has 34·11 per cent. husk.

Dr. Trabut, Economic Botanist in Algeria, reports on seeds sent to him for trial :—" Hybrids with Ligowo oats introduced into Algeria from Australia have shown constancy and immunity. The progeny of these hybrids will probably replace the Algerian varieties, the glumes of which are too hard to make them popular. These new types are winter oats, which tiller well and grow vigorously during the winter like all the varieties of A. sterilis."

AVERAGE YIELDS IN THE BREEDING PLOTS.

Variety.	1913.	1914.			1915.			1916.		
	Cowra.	Cowra.	Bathurst.	Wagga.	Cowra.	Bathurst.	Wagga.	Cowra.	Bathurst.	Wagga.
Kelsall's	1	1	5	6	1	2	1	..	6	1
Bathurst 4	4	2	1	1	4	2	5	5	10	..
Ruakura	5	5	*10	..	3	4	..	2	2	2
Lachlan	3	4	4	3	6	3	4	3	9	3
Guyra	6	5	..	3	2	..	3	4	6	6
Bathurst 5 ..	7	2	6	5	8	10	6	1	3	..
Algerian	2	6	8	7	5	8	8	7	5	4
Sunrise	9	3	11	2	8	..	2	..	8	5

* Approximate.

Kelsall's and Ruakura both have weak straw, though in some seasons it is not very noticeable.

At the Nyngan Demonstration Farm winter fodder crops are sown in ¼-acre plots to determine the best yielding crop for this dry country. The cereal crops tested were Firbank and Steinwedel wheat, Cape and skinless barley, Algerian and Sunrise oats. The oats gave the greatest yield of green fodder for the past three seasons on the average. In 1915 the yield of Algerian oats was not taken; in 1916 it beat Sunrise, but in 1917 Sunrise beat Algerian. Taking Algerian and Sunrise as equally productive, the Sunrise is to be preferred on account of the superior length of straw and early maturity, and it would seem to have a career before it in the drier parts of the State. The rainfall during growth was 618 points in 1915, 1,021 points in 1916, and 930 points in 1917.

Characteristics of Varieties—Algerian. This oat is the best hay variety for general cultivation, thriving under a wide range of climatic conditions. It stools profusely with rather narrow leaves and fine stems of good length. In order to get the best results it should be sown early and on fallowed land. It is fairly rust-resistant, and withstands drought. The grain is largely used for horse feed, and also for milling for breakfast foods. The grain is long, has a moderate per cent. of husk, and is of good flavour. The awns are slender, and the grain colour varies from very pale to fairly dark brown.

Calcutta is grown chiefly in the warmer parts of Victoria and South Australia. It is a trifle earlier than Algerian, but is not quite so fine in the straw, which is rather weak and short. The foliage is paler in colour, and the bulk of hay produced less than that from Algerian.

Red Rust Proof is similar to Algerian, but somewhat taller, and stands dry weather well. Its stooling propensities are not so great as those of Algerian, the grain is of a similar type, and the yield usually less than that of Algerian.

Ruakura. An oat imported from New Zealand, and originating as a selection from Argentine oats at the Ruakura Experiment Farm. It is a profuse stooler, paler in foliage than Algerian, and with a broader flag, but the stems are slender, making hay of good quality. Its chief recommendation is its resistance to rust; though in some districts Sunrise is superior to it in this respect. Ruakura has proved specially suitable for the coastal districts, where it seems to succeed better than Algerian.

Abundance is a white grain variety of the tree type, late maturing, growing about as high as Algerian, but the stems are coarse, and it is not suitable for hay, though it is about the best of the long-season white oats for this purpose; its yield of grain is not heavy.

Hutchinson's Potato. This is a strain of the Potato oat selected in the Glen Innes district. The straw is too coarse for hay, the grain is plump and attractive when well grown, but matures too late for a heavy crop, except in the coolest districts and when favoured with a good rainfall. The grain is in demand for feeding horses.

White Tartarian. A "side" oat, which yields remarkably well under favorable conditions. Late maturing, it has tall straw, with long, thin, white grain. This oat is not nearly so palatable to stock as Algerian, and the straw is coarse.

Guyra. White Ligowo x Algerian ripens a week earlier than Algerian, the straw is almost as fine, about the same height, and stools rather less, with bluish-green foliage and somewhat broader leaves than Algerian. The head is more compact, and the grain is of a darker brown colour, with a stout awn. The grain is plump, of medium length, with a rather thin husk. It succeeds in typical oat-growing districts.

Lachlan has the same pedigree as Guyra, but stools less, and has stronger straw. It is well adapted for the main wheat-growing areas, where it resists lodging, and matures a plump sample of grain. Its general characteristics resemble those of Guyra, though the grain is not so dark in colour.

Sunrise. This variety has already been shortly described. It is very early, with the tallest straw of any oat we have grown, though not stouter than a well-grown sample of Algerian. It stools sparsely, and is adapted for dry districts, and wherever a quickly-grown crop is wanted. It escapes rust to a great extent, and the grain is greyish white, large, and well developed.

Oats as a Rotation Crop with wheat fill a useful place as oats are not liable to the attack of the Take All fungus to any extent. Flag Smut, too, which is becoming so prevalent in the wheat crop, has not been found in oats. A rotation which is much practised in the wheat districts is 1 wheat, 2 oats, 3 bare fallow. This rotation is satisfactory if the oat crop is merely wanted for hay as a secondary consideration to the wheat grain crop. Where oats are grown for grain or a main hay crop, a year of fallow in the drier districts should alternate with each cereal crop. In districts with a fair rainfall, peas or rape can be sown instead of having a bare fallow, and even barley may be substituted.

Extension of Oat-breeding Work.—It is suggested that a farm be set apart in Victoria and one in Tasmania for testing pure lines taken from commercial varieties, also importations from abroad, as well as for cross breeding and selection. Strains and varieties found promising at the central breeding station should be grown at Government Experiment Farms and private farms on the lines of the American extension work. Ex-students from an agricultural college, who have an aptitude for an occupation of this kind, should be engaged as inspectors or explorers, each being allotted a separate district. They would visit private farms and select desirable plants from oat crops, and start ear-to-row plots on these farms in competition with the locally-grown variety, thus enlisting the interest and sympathy of the farmer. The inspector would plant and attend to the plots subsequently in so far as time would permit, and superintend the harvesting. Promising selections made on local farms would be sent on to the central breeding station and tested on a larger scale. In New South Wales the farmers' experiment plots provide for this in all the representative farming districts. The local State schools should be supplied with small packets of seed of superior varieties in order to interest country boys in the work, and oat-growing competitions might be started by the agricultural society for the district. It is in any case desirable that the central breeding station should be separated from a Government Experiment or Demonstration Farm. Members of Parliament fail to understand that experiment work of this kind is not self-supporting, and cannot be expected in itself to be a paying concern. The late Mr. Farrer never made his farm pay from sales of seed wheat, though Professor Watt makes a conservative estimate that his work has enhanced the returns in this country from wheat growing by £800,000 annually.

If tacked on to a Government farm, the plant-breeding work becomes merely one of the branches of that particular farm, and in regard to cultural operations has to wait its turn ; so that favorable opportunities are sometimes allowed to pass for lack of labour, horses, or implements. Experiment work ostensibly has first consideration, but in reality it is so clear that Parliament looks for a good monetary return at the end of the year that the farm manager naturally gives the commercial aspect his first attention.

Diseases in Oats.—Rust is the most serious disease attacking oats, and Algerian has now become rather susceptible under some circumstances, though it used to be relatively free. The Ruakura oat is most resistant, or, strictly speaking, most rust free of any variety we have at present. In the inland districts oats are seldom seriously affected, but in coastal regions the crop is sometimes a failure from this cause. Early maturity often enables a variety to escape rust, and this is the case with Ruakura and Sunrise. It is our experience that an early ripening variety of this description will give better returns than an oat which has a degree of resistance to the disease by reason of its tough cuticle, glaucous foliage colour, and longer growing season. Loose smut is troublesome, more especially in late maturing oats, and it is common to find it in commercial samples or bulks of seed received from farmers. When diseased plants are carefully removed from the crop as soon as observed, we find smut causes little trouble. Diseased patches are apt to occur in oats, the common symptoms being excessive reddening or purpling of the straw, no heads or very few heads are formed, the whole plant is dwarfed and starved in appearance, and pulls up readily as if the roots were rotten. Take All has been found in oats, but the condition mentioned is often seen without the Take All fungus being discovered.

B.—Barley.

This cereal is not grown to the extent it deserves, and the demand for seed amongst farmers is very limited. The three types grown are known as Malting, Cape, and Skinless. The Malting barleys are either of the Chevalier two-rowed type, with a long slender curved head, or the Standwell type, two-rowed, with a broader and shorter head than the Chevalier. The crop is sold to brewers if the sample is satisfactory, or used for stock feeding if the grain is damaged or badly grown, or if the price is low. The six-row variety known as Cape is a productive sort, with grain of a somewhat dark tint and less plump than that of the malting type. It has also a higher percentage of husk and of protein, and brewers like a proportion of six-row barley to mix with the grain of the two-row sorts in order to facilitate drainage in the mash tun. Cape barley, however, is principally used for green fodder, though the grain is also used for stock. Skinless or Nepaul barley has a naked grain, not unlike that of wheat, except that both ends are pointed in shape. Skinless barley is chiefly used for green fodder, providing the earliest growth of all cereal crops. It is most useful for dairymen, providing a succulent forage in the early spring before wheat and oats are ready for feeding. A succession of fodder may be had by sowing Skinless barley first, followed by Cape, wheat, and oats.

Advantages.—As a rotation crop with wheat, barley has desirable qualities. Although it belongs to the cereal group, its roots are more fibrous than those of wheat, and remain close to the surface instead of penetrating to a depth of 6 feet, as is the case with wheat. Barley is less apt to cause hoven in sheep than rape when used as a catch crop. The price of barley—a good malting sample—is higher than that of wheat. The yield is almost always greater, and diseases affecting barley are fewer than those to which wheat is liable. For instance, rust is not to be reckoned with. Mr. McKeown, of the Wagga Experiment Farm, has had considerable experience with barley, and with him the yield of barley on the average has exceeded that of wheat by 7 bushels per acre. Bearing in mind the difference in weight per bushel, barley has given better returns than wheat at the Bathurst Experiment Farm, and for a period of eight years Professor Perkins of South Australia obtained an average of 36 bushels 23 lbs. of six-row barley, as against 18 bushels 32 lbs. from wheat for the same period.

Disadvantages.—To present the case fairly for the barley crop, it must be said that there are certain drawbacks which should be weighed by farmers. As Mr. C. Jeffries-Britten, of Tamworth, says—" The market is limited, and in the event of a surplus shippers do not buy for export. If barley is not good enough for malting it is very difficult to sell it at all. Cutworms are destructive in some seasons. Buyers of New South Wales and Queensland barleys are at a disadvantage on account of having to make a price at the end of November. In Victoria the market does not open until January, and as this State is the chief malting centre of the Commonwealth, its prices govern the market for malt throughout Australia." Another authority remarks that—" The difference between a prime malting sample and what is not often amounts to 1s. 6d. per bushel and more. Malting barley requires careful cultivation and treatment, favorable weather, and careful harvesting; rain discolours, dry weather shrivels the grain. . . . When there is a full supply of barley on the market the merchant cuts down prices on the excuse of poor quality. A few years ago farmers were urged to grow barley, and the yield turning out favorably, buyers reduced prices on the score of inferior quality. Farmers have no redress, as there is very little export trade. If weather, weeds, or prices are against the crop, there is no inducement to cut for hay, as barley is not satisfactory for this purpose ; the awns are liable sometimes to give horses sore mouths, and the fodder is not so palatable as that of wheat or oats."

Barley for Horse Feed.—Our veterinary officers recommend barley grain for horses in dry districts where oats are not much grown, and it is coming more into favour in certain parts of Victoria for this purpose. The grain should be either crushed or soaked. Professor Perkins says—" In Asia, Africa, and Southern Europe oats are never fed to horses, they are given barley and straw. When short of hay one year at the Roseworthy College the horses were fed on barley and straw, and they never looked or worked better than they did that year."

Two-rowed versus Six-rowed Barley.—It is evident that there is a larger amount of food material to be transferred to the head in the case of six-row than in two-row barley ; so that the grain of the latter will naturally be more fully developed. Dr. Mann and Dr. Harlan, of U.S. America, in their experiments for the Bureau of Plant Industry, have shown that " six-row barley consists of two central and four lateral rows in which the members of the first differentiate from the others by variation of properties which seem to have a bearing on yield and the development of the future plants. So that, on account of this structural constitution, which undoubtedly finds expression during growth, six-row barley is not an absolutely ideal malting variety." It might be noted here that a six-row sample may be distinguished from two-row barley by the presence of two smaller twisted grains to each large straight one ; in two-rowed barley the crease is straight, there are no grains askew in this respect.

Yielding Qualities.—We have found the six-row type to yield uniformly better than the two-row at Cowra, and this seems to be the experience at Werribee and Roseworthy. In cool climates there appears to be less difference in yield between the two types, but in the warmer districts the six-row type succeeds best. In the arid districts of America the Skinless barleys find favour and they do well here, but a second crop does not come after cutting or feeding off as with the awned six-row type. The latter are more generally useful under like conditions with us. In America two-row barleys are generally poor yielding. The American brewing type is six-rowed and of high protein content ; they yield much better under American conditions as a rule than the two-row types.

The Class of Grain required by Brewers is that of the two-row type in Australia, although indications point to a more extended use of a good type of six-row barley, which is so universally employed in America. In September, 1910, we received a collection of 86 native six-row barleys from Dr. Trabut, of the Service Botanique, Algeria. These were grown in 1911, and by selection in succeeding years we have isolated No. 36 and No. 49 as the most productive types. These are of good substance and colour, resembling Cape barley, but of better quality. Samples grown at Cowra were sent to Messrs, Barrett Bros. and Burston and Co. Pty. Ltd., of Melbourne, in April, 1913. who reported that "it is difficult to judge these barleys for seed without a thorough knowledge of their original type; but most of them we think would throw good barley, given favorable soil, climate, growth, and ripening conditions—in fact, these latter are essentials, and really have as much to do with the quality of the grain as the original type. For instance, we have sent the finest Chevalier and American and Oregon Cape barleys procurable into certain districts, and even in one season (a good one for the district) they absolutely lose their type from a malting point of view, and the longer they are sown in that district the coarser they get. No. 36 is an excellent type." Samples of six-row barleys grown at Cowra in 1916 were submitted to Messrs. Tooth and Co., of Sydney, who reported as follows:—" Our maltster tells me they are absolutely the finest lot of barleys of this class he has so far seen, and, from his point of view, places them in the following order:—(1) No. 36, (2) No. 49, (3) Chilian. . . . We are anxious for the coming season to encourage farmers to grow 6-row barleys, and would be indeed glad if we could obtain supplies of seed of any of the lines of which you sent us samples." Thus it appears that No. 36 barley is not losing its type under our conditions, after six years of cultivation.

"*Chilian.*"—This seed was received from Messrs. Tooth and Co., who imported it from Chili. The head resembles that of Cape barley, but the colour of the grain is pale yellow, and does not show the bluish tint characteristic of Cape. This variety compares rather well with Cape in point of yield, and the grain is of better quality. In the crop grown from the imported seed were found two or three plants of two-row barley, which had short straw and stooled well. It yielded heavily last season, and promises to become a useful variety, the short straw making it less liable to lodging than the malting barleys in general cultivation. The grain is very suitable for brewing purposes.

Crossing.—A number of the standard varieties grown are artificial crossbreds; among others, Standwell, Maltster, Brewers' Favorite, and Invincible. In U.S.A. Bulletin 148, C. P. Bull states that "Crossing, even though three years more are required than with pure-line selection, will prove to be the better method for ultimate improvement, as shown by the nursery yields. This, however, does not preclude the value of the pure-line method of breeding which is undisputed. For two years the field plots showed an increase of 2·7 bushels per acre in favour of crossed stocks."

Some seed of the wild wheat Triticum dicoccum dicoccoides, discovered in Palestine by Aaronsolm, was received from the U.S.A. Department of Agriculture, and sown in 1912. In this were found two or three plants of wild barley—Hordeum spontaneum. This resembles two-row barley, but differs from the latter in having an articulate axis, a longer and stiffer beard, and more hairiness. The heads are extremely brittle, and readily fall to pieces when ripe. This barley was crossed with the Standwell variety, and fifteen grains were secured. In the same year Kinver barley was crossed with pollen from the wild barley, and seventeen grains resulted. The F^1 crossbred plants were more vigorous than those of the mother sown alongside in each case. They were uniformly of the Chevalier type, and most of them shattered easily. The plants selected had grain which adhered more or less firmly to the rachis and resembled malting barley grain in some cases; in others it was intermediate in character. In 1916 the best strains of the crossbreds (F^4 generation) compared favorably with Kinver, Standwell, and the two-row selection from Chilian in productiveness. Their straw tends to be stronger, the plants more drought resistant than ordinary malting barleys, and the grain is larger. The awns are stouter, though some strains have awns much resembling those of Kinver or Standwell. The crossbreds have a darker, narrower, and more healthy looking foliage, and the leaves show less yellowing after continuous rains than Kinver and Standwell. It will probably take longer to fix an improved variety from these two crosses than in the case of two nearly related varieties, but a hardier type should eventually result from the selection.

My assistant at the Wagga Experiment Farm has crossed a two-row naked awned barley with ordinary Skinless, also Kinver malting barley with the two-row naked awned type. Among other variations the latter cross gave rise to the six-row bearded type. A selection from these of the Skinless type appears to yield better than ordinary Skinless barley.

Method of Crossing.—The flowers to be crossed are emasculated before the head has emerged from the sheath, early in the morning being the best time, the sun's heat soon dries up the tender tissues of the plant when exposed. The top and bottom flowers are cut off and the central flowers about the middle of the head are worked upon. The enveloping glumes are cut off above the flowering organs, and after emasculation pollen from the intended sire is introduced. If well developed flowers are employed as mothers and good pollen is used the crossing can be done with safety immediately after emasculation. The head is then wrapped in muslin till the grain is ready to harvest.

Natural Crossbreds.—Mr. Peacock, of the Bathurst Experiment Farm, found a natural crossbred in Standwell barley which gave rise to the following types which breed true:—Two-row awnless, six-row awnless, and six-row awned.

Points aimed at in Selection.—It is realized that barley breeding is hardly started in New South Wales, so that we are not in a position to say much on this head. The main consideration is yield of grain, sufficiently strong straw, a bright plump pale-coloured grain which germinates vigorously and matures early. Evenness of ripening is important and non-shattering of grain. The most reliable field note with regard to barleys is the date at which the awns protrude. This determines the relative earliness of the varieties. The date of ripening is often difficult to fix; in some seasons barleys ripen off unevenly. When the warm weather begins they mature very quickly. Stooling capacity and denseness of ear, also width of leaves, are other characters useful in differentiating varieties.

Diseases.—We sometimes find barley plants withering off prematurely, of stunted growth, and usually failing to produce grain. The attack resembles that of Take All in wheat, there is no blackening at the base of the plant, however. The biologist finds that the disease is due to Helminthosporium gramineum. Barley rust is usually present but seems to do little harm. Smut is very common in Cape barley, but we have not found the disease in the six-row types received from Algeria. There is no reason why smut should be feared if a clean stock of seed is bred up and machines are not used on a diseased crop.

Harvesting.—Mr. Jeffries-Britten, of Tamworth, says—" There is no doubt the malting quality is much improved if the barley is reaped, stacked for some time, and then threshed ; but as the grower gets little or no more for barley so harvested than for grain carefully taken off with the harvester or stripper, he is not likely to go to the extra expense entailed by threshing after reaping and stacking. Most novices do not realize the importance of extreme care in adjusting their harvester so that the skin of the grain is not broken. They cannot understand why barley should be treated differently from wheat. Barley is often spoilt for malting by being stripped before fully ripe, the grain as a result becoming heated in the bags. Farmers are recommended to sow a quarter to a fifth of their cultivation area with barley. They will thus have enough harvesting machinery to get the crop off within a week, and this is important because the grain must be dead ripe before starting, and after standing ripe for more than a week the heads break off the stalks very easily. Many cases have been known of farmers getting a gross return of £7–£8 per acre from a small area of barley, as against £5–£6 per acre from a large area of wheat ; next year they think it wise to sow all with barley, and not having sufficient plant to harvest the crop in a week or ten days, they are disappointed with the result, and give up barley growing in disgust."

C.—General.

Field Methods with Oats and Barleys.—The row system is employed instead of the square plot for by this means a larger number of individuals can be isolated and observed. This method is preferable with a limited area, so long as the plots are repeated. We employ three to six plots of each variety or strain to be tested, commonly three ; but at Nyngan Demonstration Farm, where the soil is uneven, we use twelve plots of each variety. A like number of plots of the check variety are sown as a rule so that its yield may be computed with that of the others. A buffer plot is sown with seed of the check variety in every alternate drill or plot. The yield of the buffers is obtained, a record of their performance being useful for comparison. When sufficient seed of an approved variety has been obtained, a rectangular plot is sown with a seed drill to test it under field conditions. If a larger area and more assistance were available the square plot could be adopted in the earlier stages of breeding and selection. Single seeds are sown at 5–6 inches apart, the rows being 2 links apart, and commonly 30 links long. For multiplying plots rows 100 links long are employed. The soil is worked with good tilth and the plots measured out, drills being opened with a hand cultivator with ridging-plough attachments. This implement is used for opening and covering in drills. The seed is dropped by hand 1½ inches deep, and the soil left in a slightly ridged condition favoring germination. If the seed is shrivelled or badly grown it is carefully screened or hand picked. In the case of oats hand picking is necessary to separate double grains in some instances.

Records.—Every introduced variety is given a registered number, which is entered in a book, and the card system is employed for recording in the "Planting Register"—(1) The name of the variety, (2) registered number, (3) year grown, (4) locality, (5) plot or area, (6) the source of seed, whether a new variety or one grown previously.

A strain of seed can be traced back to any particular year by means of the number and letter of the plot in which it is grown each season. Crossbreds are not given a registered number until they become fixed in their characteristics. The various strains selected from any given cross are distinguished by their plot letter and number each season. Oats and barleys are tested at the Cowra, Wagga, Bathurst, Glen Innes, Hawkesbury College, and Nyngan Farms; barleys to a very limited extent at the Hawkesbury College, and at Nyngan the climate is unsuitable for oats, except the very early varieties. Under nomenclature records we have cards giving the following notes taken on oat varieties during the season, the values, where possible, being indicated by numbers :—

1. Locality where grown. 2. Plot. 3. Date of sowing. 4. Variety. 5. Source of seed. 6. Germination.

Young growth.—1. Darkness of tint. 2. Creeping habit. 3. Breadth of leaf.

Heading time.—1. Date ears peeping. 2. Degree of stooling. 3. No. plants marked early. 4. Uniformity of type.

Hay harvesting stage.—1. Straw green, yellowish, or purple. 2. Abundance of flag. 3. Coarseness of straw. 4. Height of straw. 5. Degree of rust. 6. Suitability for hay.

Mature plant.—1. Date ripe. 2. Neck crinkled or straight. 3. Panicle spreading "tree" type; compact "tree" type.

The oat record form is adapted for barleys, a special form has not yet been compiled.

A variety is given a three years' test before being rejected.

Plant Breeding in other Countries.—Six years ago there were in Germany 43 breeders of winter rye, 3 of spring rye, 61 of winter wheat, 23 of spring wheat, 5 of winter barley, 60 of spring barley, 53 of oats, 23 of fodder beets, 21 of sugar beets, 17 of potatoes, 28 of legumes in both public and private institutions.

At Svalof, in Sweden, as is well known, a large institution is maintained, which has the confidence of the farming population of the country. In America the various State Experiment Stations are liberally endowed for plant breeding work and, besides, cross breeding, import new varieties and test pure lines from commercial varieties on a large scale.

Oat and Barley Breeding in New South Wales, in conjunction with wheat breeding, is carried on at the Cowra Experiment Farm, where 2 acres are devoted to the experiments each season. This is the main breeding station. Plots for testing and selection are also conducted at the Wagga, Bathurst, Glen Innes, Nyngan, and Grafton Farms, and the Hawkesbury College.

The plots are under the control of the Farm Experimentalist, who directs the work in addition to his other duties in assisting the Farm Manager to conduct the various experiments bearing on general farm practice. Plant-breeding work loses much of its value if not carried out thoroughly, and on a sufficiently large scale. It is true the late Mr. Farrer achieved remarkable results with breeding experiments on a very restricted scale—he never had more than 1½ acres of plots at Lambrigg, and usually one assistant. The Economic Botanist of India, Mr. A. Howard, speaking of cross breeding, says—" Hybrids can be fixed in all respects if the work is properly carried out, and if all the cultures are sown and reaped plant by plant till the fourth or fifth generation at least. This, however, is not easy unless the supply of labour is adequate. Thus in our crosses for strength of straw and rust resistance, we sow about 1,000 plants in the F^2, and all carried forward to future generations are sown singly grain by grain and reaped as separate plants." If Farrer had worked with sufficient labour he would have had 20 acres of crossbreds alone undergoing selection each season. It is our practice now to make very few crosses, and to sow a very large number of plants in the F^2 generation, thus affording abundant material for selection. Farrer, on the other hand, made a great number of crosses, and planted comparatively few grains from each.

Introduced Varieties are tested to see if they become sufficiently acclimatized to suit our districts. European and American sorts of oats are very rarely entirely successful when grown in our climate. They usually require to be crossed with a variety which thrives in warm climates. Barleys, too, unless used to comparatively warm summers, do not yield well here. The Indian Government has had a like experience, introduced varieties of wheat are usually too late for India, becoming parched by hot winds. The only imported kinds likely to be of value in this country are early maturing sorts from localities somewhat similar in climatic conditions to those of Australia, such as Africa, the Mediterranean, South America, and India. For instance, White Ligowo, one of the best imported oats, has been grown for many years by our Department, and the average yield for four years in field variety trials at the Glen Innes Experiment Farm, has been 18·76 bushels per acre, as against 35·99 bushels per acre for Algerian oats for the same period. Guyra for three years out of four gave a yield of 35·19 bushels per acre, practically equal to that of Algerian, and a more attractive sample.

Research Work and Plant Breeding.—Mr. A. D. Shamel, in the U.S.A. *Year-Book* 1907, p. 222, says—" The careful and exact experiments of the scientific investigator, and the keeping of the necessary records require men who are specially trained and who devote their time and energy wholly to this work. The art of breeding is the work of growers who, by long experience with the crops from a commercial stand-point, become accurate judges of the value of plants for economic cultivation. It has often happened that workers attempting to carry on both lines of work have failed of any high achievements in either line. The plant breeder applies the facts worked out by the scientific investigator in the production of new and improved varieties of crops. The increase of knowledge of breeding" (due to research work) " has enabled breeders to achieve results more quickly than heretofore. Notwithstanding these short cuts, the fact still remains that really valuable varieties have been developed and brought into general use gradually, and only after years of patient work . . . The plant-breeders work becomes more valauble in proportion to the length of time spent in the improvement of the varieties. . . . The really important factor of all breeding is the development of the expert judgment necessary for practical breeding and seed selection."

Discussion of Mr. Pridham's Paper.

Mr. McAlpine stated that for three years he had recorded the exact number of natural crosses met with in wheat, oats, and barley, and he found that natural crosses were most frequent in wheat. He would be glad to know if others had found the same.

Mr. Pridham stated that his experience was the same.

Mr. Richardson expressed the opinion that there were great opportunities open to those who would take up the improvement of oats and barley, which had been very much neglected in Australia, Mr. Pridham's work standing alone. In particular, advantage should be taken of the many varieties that exist, and the prolific varieties selected and isolated.

He mentioned that though barley was largely grown for hay in the Western United States, in Australia attempts to use it in this way were largely failures, the hay proving indigestible. He attributed this to the fact that the barley was not cut early enough. It should be cut just as the green barley heads are coming out. When cut at this stage the hay produced is more palatable than oaten or wheaten hay.

He emphasized the importance of sowing second-generation seed separately, so that it could be ascertained which types were fixed. The difficulty was the amount of space required. He mentioned that in oats all the different tints appear to be Mendelian dominants to colourless or white.

Mr. Pye referred to Mr. Pridham's description of his method of emasculating oats which appeared to be similar to that usually adopted with wheat. Personally, he had found that this involved waiting till the exact moment when the flowers were opening, and he, therefore, cut across the tops of the flowers so as to emasculate them from above. He could sympathize with Mr. Pridham in the difficulty experienced on a mixed farm in obtaining assistance at the time when it was most needed in the experimental work.

Prof. Flynn referred to the suggestion that an oat breeding station should be established in Tasmania, and asked if the author could give him more detailed suggestions which he could lay before his Government.

Mr. Pridham, in replying, thanked Mr. Pye for his suggestion as to crossing oats, as the method described would simplify his work. He had experienced the difficulty referred to by Mr. Richardson that growing single seeds for several generations meant a very large area, but he thought the results fully justified this. He suggested that in Tasmania a farm should be established for testing varieties of oats and breeding varieties suitable for the country. From these, pure seed should be raised and distributed to farmers. A farm devoted purely to work on these lines should not cost very much, and he would be pleased to give information as to the cost of the smaller farms of this type in New South Wales.

MAIZE BREEDING.

By H. Wenholz, B.Sc. (Agr.), Inspector of Agriculture, New South Wales.

We might usher in the subject of maize breeding by saying that it differs distinctly from that of breeding other cereal crops, not only in the methods employed, but also in the results obtained in a comparatively short time.

In the first place the term " breeding " as applied to maize might conjure up false visions of the crossing of two definite parents to produce a resultant new variety as is done in the case of wheat and other cereals, but this notion must be dispelled. Maize differs from most other cereals in being readily cross-fertilized, and is, in fact, dependent on cross-fertilization from neighbouring plants in the field for the formation of its grain. Indeed, the initial work in maize breeding or improvement consists largely in many cases in eliminating from a variety the impurities represented by previous crossing with other varieties. It will be seen, therefore, that it is impossible to have a central maize-breeding station for the improvement of maize varieties by breeding and selection as is possible in the case of wheat and other cereals. We have realized that the improvement of maize consists largely in selection within the variety, and we have therefore restricted the Government Experiment Farms in New South Wales to the use of one variety, which from previous experience has been found to be the best for that particular district. The methods followed for the improvement of the variety will be described later. Now, although we have a number of Experiment Farms in New South Wales, there are some important maize districts in the State which have different climatic and soil conditions from those of the nearest Experiment Farm, and where it has been found that a different variety of maize succeeds best. For instance, the Inverell district, which is only 42 miles from Glen Innes Experiment Farm, has a lower elevation by over 1,500 feet and a warmer climate and richer soil than the latter district. Experiments have shown that the variety which succeeds best at Glen Innes is easily beaten in yield by another variety of maize at Inverell. In such cases the policy of the Department of Agriculture has been to select a good progressive farmer in the district and establish a permanent seed improvement plot on his land, supervising the work of selection, and placing him in a position to supply the demand of the district for improved and acclimatized seed of a variety of maize which has been found by experience to be the most successful for that district.

Seeing that maize is so largely dependent on cross-fertilization, and that this fact has such an intimate connexion with the methods of improvement followed, I may be pardoned for dealing in a little more detail with the botany of fertilization of this crop. At the top of the maize plant is situated the tassel which contains the male flowers, while the silk which protrudes from the end of the husk (which envelopes the young ear) is the female organ of the plant. Each strand or " style " of the silk is attached to an embryo grain on the cob, and is stigmatic throughout its whole length. Pollen falls by gravity from the tassels on to the silks, usually from neighbouring plants, and fertilization is thus effected. One important observation with regard to fertilization is that the silks from the butt of the cob appear first, and those from the tip of the cob several days later. As the tasselling usually starts a few days before the silks appear, we can readily understand why we get so many ears with bare or imperfectly filled tips, the formation of these grains at the tip of the ear depending on the tip silks being pollinated from neighbouring flowering tassels in the field.

Now with the large size of an ear of maize as compared with other cereals, its ease of handling, the large number of grains it contains, and the small number of ears required to plant a given area, in addition to the easily visible different characters in the ear, it is not surprising that the ear of maize has been studied with regard to type or ear characters, and their possible relation to yield. The conclusion has been reached that there are certain fundamental characters which are apparently associated with yield, and which are set up as an ideal to strive for in selection. These fundamental characters are chiefly desirable features in length and shape of ear, weight of ear and percentage of shelled grain, space between the rows, filling and character of the butts and tips, depth of grain, and size of core. The ideal ear, or the ear with many of these desirable characters highly developed has not, however, been found by experiment to be positively correlated with yielding capacity under all conditions. We are collecting data in New South Wales to discover what visible characters in the ear, if any, are associated with yielding capacity, and we hope to be able to show some correlation between type and yield at least for particular districts which differ appreciably in climatic and soil conditions. From initial work in this direction it appears that, although the depth of the grain is correlated with yielding capacity in a late maturing variety of maize on the coast, this correlation does not seem to exist with early varieties on the tablelands. Now, most maize growers say that they like to select ears with a deep grain and a small core. It seems that this smallness of core is a fetish which has been carried too far in some districts. Our experiments indicate that in districts of good rainfall there is a correlation between a moderate-sized core and good yielding capacity. The reverse, however, is true in districts of scanty rainfall, such as the Western Slopes, so that it appears that smallness of core is a character somewhat related to drought resistance, but not to very high yields. These instances will serve to show that we are somewhat justified in expecting to find some definite correlations between ear characters and yield for localities with particular soil and climatic conditions.

With regard to some of the other visible or measurable characters of seed ears, the most important is probably the weight. Since from 75 to 90 per cent. of the total weight of the ear consists of grain, it is important to select those ears which are heavy, especially in proportion to their size when dry. We do not ask practical farmers to weigh their seed ears on a balance or scales to get the exact weight, but after some practice it will be found easy to select the heavy ears by rough estimation of the weight in the hand. One who keeps this in mind will find several ears of good size and appearance in the reject heap at the end of the day's work. The outside appearance of the ear is sometimes deceptive, but the rough estimation of the weight is found to be a very reliable guide in selecting ears with good solid weighty grain.

An ear of cylindrical shape is also more desirable than one which tapers rapidly from butt to tip. as the latter not only shells less grain, but also contains grain which on approaching the tip becomes gradually narrower and shallower, so that a large amount must be discarded from the ear to obtain grain of uniform regular size for planting when such ears are used for seed.

Returning to the question of size of core, it is of course possible to err on the side of having a core of excessive thickness. Such cores take a considerable time to dry out, and in moist districts constitute a menace in the storage heap, in that they not only mould themselves, but also impart their moisture and mould to a number of ears in their proximity in the heap.

In the selection of seed ears, greater attention is required in selection for uniformity in the appearance, size, and shape of the ears, and in the character of the indentation of the grain. Greater uniformity in these characters would mean more uniformity in the maturing of the crop, and consequently also greater uniformity in flowering, which has been found to be directly associated with a smaller percentage of barren stalks.

Seeing that maize is so easily cross-fertilized, it seems that at least one progressive step is made by selecting the best seed ears obtainable and planting them in a special seed plot of limited area—about an acre in size. This plot is isolated from all other maize by removing it at least half-a-mile from other maize, or by planting it three weeks or so before or after any other maize adjacent to it. We see that by having all our best seed in this special seed plot, we have cross-fertilization going on only between these most desirable types, and we are eliminating those poorer types which we would have to include in a field of larger area.

We have now to deal with the source of the seed. Experiments in many parts of the State have proved that acclimatization plays an important part in increasing the yield of a variety. This factor seems to have a greater effect in this direction with maize than with any other crop. In very few instances has an increase of less than 4 bushels per acre been obtained in favour of acclimatized seed over that of the same variety introduced from another locality. It also seems that there is an advantage in having seed maize suited to the particular soil conditions under which it is to be grown, especially where these conditions differ markedly from the average. Let me give a particular instance. At Berry Experiment Farm on the South Coast, where the soil is heavy and not well drained, and where the rainfall is high, a poor crop of 25 bushels per acre was produced in 1915. The quality of seed obtained from this crop was so poor that some hesitation was made about using it for seed. However, it was decided to use some of it, and to introduce some fresh seed of good quality and appearance from an excellent crop of the same variety grown 15 miles distant. On testing these two sources of seed the locally produced seed of poor quality and appearance yielded 52 bushels per acre and the introduced seed of good quality 7 bushels per acre less. It appears from this experiment that we should also have our seed maize suited to the soil conditions as well as the climate. Seed maize should therefore be acclimated, and, if we might coin a word, assoilated.

Having dealt with the main characters observable in seed ears of maize, we have now to face the fact that we have taken no cognizance of the field characters of the mother plants from which our selections have been made. The maize plant is so large, compared with that of other cereals, that it easily bears some study as to the characters which distinguish different stalks in the field. In the same variety we get differences in the height of the stalk, the height of the ear on the stalk, the number of ears on the stalk, the length of the shank which supports the ear, the covering or protection afforded by the husk, and the inclination or angle of droop of the ear to the stalk.

The most important point in field selection is that we can see which are those plants that have produced a large ear or one of normal size under average conditions. We do not know when selecting our largest ears in the barn or shed that we are not choosing one which has had particular advantages during its growth, such as an extra space or more favorable situation. These large ears produced under good conditions have not been found to constitute a better yielding strain than ears of moderate size produced under normal or even adverse conditions in the field.

Plants which produce a large ear for the amount of stalk grown constitute a valuable basis for improvement of the yield by field selection. In some of our maize districts on the coast considerable trouble is occasioned at harvesting by having the ears too high on the stalk, and we are seeking to reduce this height, and thus cheapen the cost of harvesting, at the same time maintaining or increasing the yield. As to the advisability of selecting for two or more ears per stalk, our experience at present indicates that this is not of any advantage in increasing the yield, except where the first ear is up to normal size. In those districts where the autumn or winter is wet, a large amount of maize is spoilt in those ears which stand erect at maturity (due to a short thick supporting shank), especially also if the husk covering is deficient. On the North Coast, where insect pests such as weevil and grain moth are abundant, much damage is done where the husk does not completely cover the tip of the ear, for in those ears which are completely and tightly covered by the husk no trace of weevil can be found. We hope by increasing the number of such weevil-resistant ears by selection to increase the safe storage period of maize, which is an important factor in these districts. We have obtained increases in yield up to 7 bushels per acre from field-selected seed over that selected in the barn.

Having now considered all the visible factors in selection, both in the ear itself and in the mother plant in the field, we may think perhaps that we have reached the end of our tether as far as improvement by selection is concerned. Such, however, is not the case. It is only within the last four years that maize breeding with a definite view to improvement in the yield and quality of the grain has been systematically undertaken in New South Wales by the method which I am about to describe to you. It is only some fifteen or twenty years ago that this system was commenced in the United States of America, which country is the admiration and wonder of the whole world for its immense production of maize. This method, which easily transcends all others in obtaining results, is known as improvement by the "ear-to-row" test. This is simply a test in individual rows of equal length of grain from separate ears after the manner of the head-row test with wheat, but this test is productive of more striking results with maize than perhaps with any other crop. We select ears of maize to the best of our ability as far as the hand and eye can judge to be the best yielders, but when we compare these ears in the actual performance test we get remarkable differences in yield, differences that we scarcely ever expected. I do not wish to go into detail concerning the cause of these differences just here, as it is rather technical, and will take some time to explain, but we are chiefly concerned with the results obtained. One of our typical test plots last season gave us such huge differences between the individual rows that the lowest and highest weights harvested from individual rows of equal length were 85 and 225 lbs. of grain respectively. In order that these yields may be corrected for soil differences, we plant every fifth row with bulk-selected seed of the same variety, and in the particular plot referred to these check rows gave no greater variation than 30 lbs. per row, the range being from 140 lbs. to 170 lbs. The length of the rows in this plot was a little over 4 chains.

Now, the method of procedure adopted to turn this difference to account in producing a higher yielding strain of maize requires a little further elaboration. In the first place, in order to plant the ear-row test we use only portion of the ear, and save the residue till the following year. From what I have already told you regarding the first appearance of the butt silks and the later appearance of the tip silks, it is desirable that we should shell the grain in a longitudinal direction on the ear, leaving the residue on the ear with half the number of rows or more intact. By marking these ear residues with a number corresponding to the row in which its grain has been planted, we are then able to say, when the results of the test are known, which are high-yielding ears and *vice versâ*. By planting the residues of the best eight or ten of the ears which have been initially selected (which were about 40 or 50) and keeping this plot isolated from other maize, we now have in this plot all our cross-fertilization going on between strains of proved high-yielding capacity. This plot we call the " breeding plot." We can still further improve on this practice in the breeding plot by sowing the residue of the highest yielding ear or two in the centre of the plot, and the next best residues on either side and detasselling the centre row or rows so as to have them cross-fertilized by the adjacent rows on each side. Apart from the fact that seed from detasselled plants generally constitutes a source of greater vigour than that from undetasselled plants, it will be seen that by selecting seed from the detasselled rows in this breeding plot we have the best yielding strain crossed by the next best yielders, and this is the seed of improved yielding capacity that we use for sowing larger areas on the farm. We can still go a step further in improving the seed in the breeding plot by removing all weak and barren stalks before they shed pollen, and thus eliminate still further some risks of reducing the yield. The mating of individual plants has not been attempted very much, and it does not seem to promise much more than the method indicated above. In the first place, we cannot be absolutely certain in mating individual maize plants what our parents are eventually going to prove. As we are not dealing with pure lines as in wheat, we may get some poor plants in high-yielding rows as well as the good ones. We have to mate these plants, of course, at the flowering stage, and at this stage there is very little indication of the size of ear which will be produced.

In the work which has been carried out throughout the State in these ear-row tests with maize, some very useful observations have been made which have thrown considerable light on maize breeding and selection. We have found, for instance, that some rows from individual ears contain a high percentage of barren stalks, while other rows have practically none. In looking through an ordinary field of maize which has been sown with mixed seed, we have come across barren stalks, and have been apt to regard them as being due to the soil or other factors, but the ear-row tests have shown us that barren stalks are largely influenced by heredity. As would naturally be expected, we find that a high percentage of barren stalks is negatively correlated with high yield. We have also found that many of the highest yielding rows in the tests have been the most uniform in the type of ears produced, and this supports our work in the direction of attaining greater uniformity in our varieties. We are collecting a valuable lot of data in further observations of this character in our ear-row work with maize at the Experiment Farms in New South Wales. At these farms, also, accurate notes are kept on the field characters of the plant from which the selected ears have been taken, and also detailed description of the visible and measurable characters of each ear planted in the ear-row test. An endeavour will be made after the collection of five or six years' data to discover whether any of these visible or measurable characters of the mother plant (stalk and ear) are in any way correlated to yield. From the indications already quoted, it seems as if this field is promising of appreciable results.

In connexion with this work it has been found necessary to be able to give the yield of each ear used in the ear-row test as measured in bushels per acre, and at the same time be a true comparison with that of every other ear after making allowance for the variation in the check rows. This is done in the following manner :—

Take the following hypothetical case as being part of the ear-row plot :—

Row.	Ear Number.	Actual Yield.	Natural Yield.	Percentage Yield.	Yield per Acre.
		lb.	lb.		bushels.
22	Check (bulk seed) ..	60	60	100	65
23	79	68	62	68/62 x 100	65 x 68/62
24	92	74	64	74/64 x 100	65 x 74/64
25	87	82	66	82/66 x 100	65 x 82/66
26	63	68	68	68/68 x 100	65 x 68/68
27	Check (bulk seed) ..	70	70	100	65

Supposing we get two neighbouring check rows giving 60 and 70 lbs., we put down the natural yields of the intervening ear rows in arithmetic progression with the same constant difference between them. Now, the true comparison of the yield of the ear rows is, of course, the percentage yield, that is, the percentage the actual yield is of the natural yield. But, in order to get a measure of the differences between individual ears in actual bushels per acre and still keep them comparative, we must find the total actual area occupied by the check rows and calculate the average yield of the check rows from the total actual yields of these rows. We assume that this yield would have been produced on the plot if it had all been planted with bulk seed similar to that used in the check rows. The yield per acre of the ear-rows is then this average yield of the check rows (in this case 65) multiplied by the fraction—actual yield over natural yield. This gives us a very close approximation of the yielding capacity of the ear expressed in bushels per acre in a way in which the figures can be compared for different ears. The calculation of the yield in bushels per acre from the actual yield of the row and the space occupied by it would make it impossible to compare these figures for the different ears owing to the variation in the check rows.

We now come to the question of breeding maize for special requirements or for other objects than yield. I might say that, as far as our work in New South Wales has progressed, we have always kept yield in the foreground, and have considered other factors quite subsidiary.

However, breeding for such a character as early maturity is found to be necessary in cold climates such as the Tablelands, where much maize in some years is damaged or destroyed by frosts. Much loss in this direction can be avoided by the selection of early maturing plants in the field instead of the longer process of elimination of the later maturing types in the variety by gradual acclimatization. It also appears to be an almost universal practice in the United States to make a preliminary germination test of each seed ear before planting, and to discard those ears which give an unsatisfactory or weak germination. A modification of this practice is at present in operation in New South Wales in connexion with the ear-row tests, and although the practice does not seem to be as important here owing to the absence of the extremely severe winters which occur in the United States, some information appears to be arising from the investigation which promises to be of value in a slightly different direction.

In breeding for drought resistance, the greatest difficulty we have to overcome is the "blasting" effect of hot drying winds on the viability of the pollen grains, and it is this fact which has largely limited the extension of maize growing into some of the drier areas on the Western Slopes. In many cases good growth of stalk can be produced in some of these districts, but the formation of grain is prevented owing to the "killing" of the pollen by these winds. The difficulty has been somewhat side-stepped in some districts, including the Murrumbidgee Irrigation Area, by the use of a short-season variety planted late (December) which flowers during more humid weather in February, and which matures before frost. It may be possible by breeding and acclimatization to get a strain or a variety which has pollen which is more resistant to this "blasting" effect; but it must be borne in mind that the limitation of moisture in the soil seems to be also a contributing factor. Some success in this direction appears imminent in the United States with a Chinese maize with a waxy endosperm, which seems to have a drought-resistant pollen.

There is no doubt that there is considerable room for the extension of maize growing into many districts on the Western Slopes of the Tablelands, which have average rainfall of from 25 to 30 inches. In these districts many farmers find it profitable to produce 10 to 15 bushels of maize per acre on large areas, owing to the cheaper cost of production with multiple ploughs and wide harrows, and cheaper harvesting by stock as compared with the Coast. On many occasions farmers in the west have to buy considerable quantities of maize to keep their sheep alive.

In the breeding of maize for improved chemical composition, experiments have been carried out at Illinois (U.S.A.) which have shown that by selection it has been possible to evolve two strains from a variety which have a protein content of 8 and 14 per cent. respectively, and also two strains from the same maize whose oil contents are 3 and 7 per cent. respectively. Although these experiments are valuable in showing what can be done by selection in this way, no attempt has been made to work along these lines here, and it is doubtful whether the results would be of any economic value unless there is sufficient demand for a maize of improved chemical composition to justify the asking for an increased price for such improvement.

With regard to the production of new varieties of maize, I have explained before that we are not attempting very much in this direction, chiefly owing to the increased yields we seem certain of getting by the system of breeding or improvement within the variety. We have, however, tested the efficacy of first-generation of crossbred seed obtained by crossing two distinct varieties of maize. This seed was obtained by growing two varieties in alternate rows and detasselling one variety so that it would be cross-fertilized naturally by the adjacent one. In several instances this first-generation crossbred seed has out-yielded either parent. It is usually found that this increase in yield is not maintained after the first year.

In view of the value of acclimatized seed maize, it seems desirable that a good system of co-operation should be arranged with the best and most reliable farmers in each maize district, with whom work can be carried on for improvement of the variety best suited to the district. Not every farmer who grows maize will bother himself any further than the bare selection of seed ears from his crop, and we must be content to find one or two farmers in each large maize-growing district who will undertake the extra trouble involved in the breeding or improvement work for the extra price he can ask for his improved seed. In such maize districts in New South Wales not represented by the Experiment Farms we have been fortunately successful in securing reliable co-operators for this purpose. For this work an intimate knowledge of the local conditions and the type of maize likely to suit such conditions is required, which is only gained by experience.

In conclusion, I might say that, without becoming unduly optimistic as to the results obtainable by the method of improvement in the yield of maize I have just described, we have now reached the stage where we can say that it is possible to increase the yield of a variety from 10 to 20 per cent. at least in three years. In two experiments carried out last year in New South Wales to test the "stud" seed from the breeding plot against the ordinary selected seed we obtained the following result:—

Locality.	Variety.	"Stud" Seed.	Ordinary Selected.
		bushels per acre.	bushels per acre.
Hawkesbury Agricultural College, Richmond ..	Red Hogan..	78·47	67·59
Experiment Farm, Grafton*	Leaming ..	35·3	24·1

* The low yields in this instance are due to an adverse season.

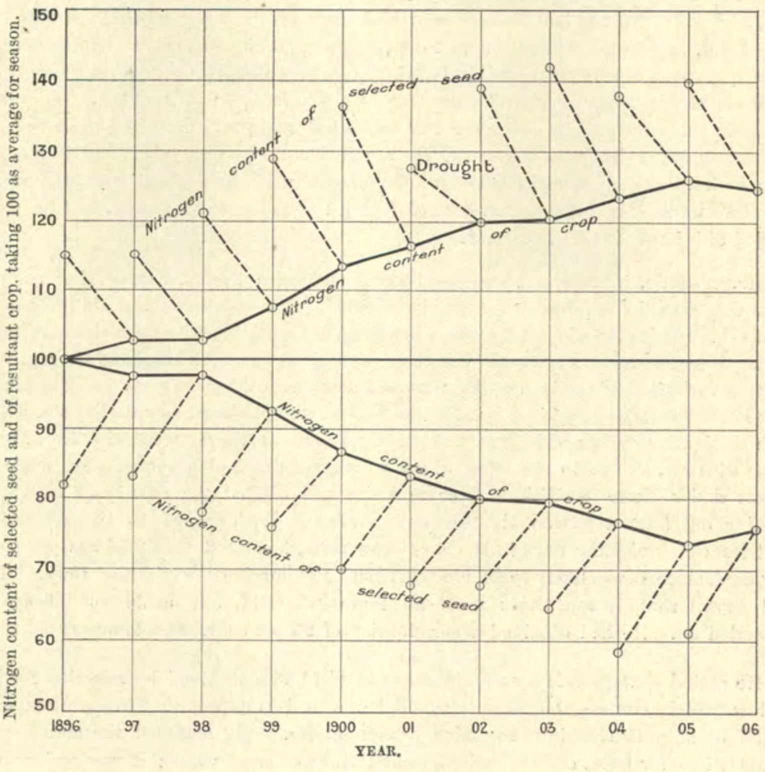
Discussion of Mr. Wenholz's Paper.

Mr. Sutton drew attention to the fact that Mr. Wenholz's work in maize selection was similar to that now adopted by wheat breeders in that the parent plants were selected as the result of performance and not of appearance. He thought that the limitation of varieties on the farm should be extended to varieties of wheat throughout Australia, where too many varieties were at present grown.

Dr. Green exhibited a diagram showing in graphic form the results obtained at Illinois by selecting maize for high and low oil and protein content respectively. The results published by the experimenters showed the analyses of the maize used as seed and the resultant crop obtained each year. These figures varied erratically and were dependent on the type of season. When, however, the mean of the percentages of protein in the high—and in the low—protein maizes, for example, was taken as a standard and the proportionate percentages of each class were plotted as in Plate II., the seasonal effect was eliminated, and it would be seen that with each succeeding year the difference between the high and low proteins was steadily increased. The only important discrepancy apparent was when the abnormal drought of 1901 made it impossible to obtain a suitable supply of high protein maize for planting in the following season.

PLATE II.

SELECTION OF MAIZE FOR PROTEIN CONTENT.



Mr. Pye stated that from his observations he had come to the conclusion that the reason why little seed was set in dry conditions, was that the silks dried up, and not that the pollen was killed, as described by Mr. Wenholz.

Prof. Watt congratulated the writer on his paper and the work he was doing. He pointed out that there was no disadvantage in growing two-year-old seed as it germinates quite well.

Prof. Paterson remarked that the methods of maize breeding adopted in New South Wales appeared to be founded on common sense. With regard to the increase of the protein and oil content of maize by selection, it would be interesting to know whether this had an effect on the yield. He had long held the view, which had been expressed by Mr. Richardson, in reference to wheat, that highest strength and highest yield could not be expected in the same variety.

Mr. Quodling stated that many of the highest yielding varieties of maize had been imported into Queensland from America, but had failed to live up to their reputations under Australian conditions. Since the ear-to-row method had become so popular, and as a result of Mr. Wenholz's work in New South Wales, this method had been taken up in Queensland with gratifying results, and in some instances last season a difference of over 40 bushels per acre was obtained between the highest and lowest yielding ears.

He referred to the experiments undertaken by school teachers, who had often in the past tested a number of varieties in a small plot, with the result that the seed became mixed. This practice had now, fortunately, been stopped. Instead, the highest yielding ears, as ascertained in ear-to-row tests were distributed to boys who entered for competitions, and in some cases phenomenal yields had been obtained, up to 135 bushels per acre, and great interest had been aroused both amongst the boys and their parents. In some cases, boys had sold seed-maize to their fathers at £1 per bushel. In the North, where quantities of soft maize are produced, and there is a heavy rainfall. which continues to June, the yields per acre are higher than in any other part of Australia, the average last year being 50 bushels per acre. A variety of maize, with a good husk covering and an ear which droops at maturity, was required under the prevalent conditions. It must be hard enough to resist troubles from weevils and climate, and must dry rapidly and store well. An improved system of drying the maize was required, and he would be glad of information on this point.

Mr. Wenholz, in replying, expressed agreement with Prof. Paterson that common sense was the chief requirement in maize breeding. The same technical ability was not required for maize breeding as for wheat breeding, most of the existing varieties of maize having been produced by practical farmers, and since the work consisted in improving existing varieties and not in creating new ones, no such glorification could be looked for by maize breeders as was achieved by men like Farrer, who produced new varieties of wheats with distinctive names which are now widely known as Farrer wheats. He did not agree with Mr. Pye as to the effect of dry weather, as he had observed that while the tassels under these conditions became white and blasted the silks were capable of pushing out later a fresh moist stigmatic surface. With regard to the selection of seed from high-yielding rows in the ear-to-row tests, he stated that this was not generally used, since it was likely to be crossed from neighbouring low-yielding rows. Tests had shown that it sometimes gave an increased yield, but could not always be depended on. He had obtained a germination of 95 per cent. from two-year-old seed.

He stated that practically no difference in yield was obtained by selection for high or low protein content, but that it would be natural to expect that low protein maize would be later in ripening than high protein maize. He regarded the corn growing competitions for boys, conducted in Queensland, as of great value; it was easier to get a hearing from the younger generation than from the more conservative older farmers. Artificial drying of maize is unnecessary in New South Wales, but he believed that there were several drying machines in America. The "Hess" drier is said to be a good one, and there is also the "Vasino" cereal drier, a new machine manufactured in Italy.

THE APPLICATION OF STATISTICAL METHODS TO THE SELECTION OF WHEAT FOR PROLIFICACY.

By W. Heber Green, D.Sc., Lecturer in Agricultural Chemistry in the University of Melbourne.

Introduction.

The improvement of wheat by selection is at best a slow process. By cross fertilization an entirely different type may be evolved in one step, but in selection from a pure line we are dependent on the natural variation from the parental type exhibited in the progeny.

Though certainly tedious, the process would appear to be sure and comparatively simple, but its application is limited by—

(1) the amount of the variations, and

(2) our ability to detect those individuals in which the extreme variation exists.

Another factor which is involved is often referred to by experimenters as the prepotency or hereditary power of the individual to transmit its variation to its progeny.

This is the crux of animal and plant breeding.

Notable instances of speed in trotting horses, milking power in cows, and sugar content in beet are well known where the individual has possessed an almost unique prepotency. Other individuals showing considerably greater speed or milk or sugar production, as the case may be, are common but their progeny are comparatively insignificant. To quote an example referred to by Davenport :—Hambletonian, ten of whose progeny include practically all the greatest producers of trotting horses, was but an indifferent trotter.

Hundreds of horses could go the mile 30 seconds faster, and he himself was dead long before anybody knew his value as a breeder of speed.

Definition of the Problem.

We see then that the problem confronting the breeder depends on three factors :—

1. The variation of the individual from the parental type.
2. The inheritance of the character in question.
3. The ability or the luck of the experimenter in selecting the right individuals.

This is a general statement which may be applied to any animal or plant and to any quality that we wish to develop, whether it be one of the cases referred to, or, in wheat—its prolificacy, its resistance to drought or rust, or its bread-making qualities.

There is no reason to suppose that the laws governing variation and inheritance are any different for wheat than for members of other branches of the animal and plant kingdoms. But since the wheat plant is self-fertilized we need not consider the complication of double parentage.

Turning our attention to the *prolificacy of wheat*, the separate prolificacies of each individual grain in a plant will vary from the average. These separate values may be conveniently plotted in a graph in the form of a frequency curve, which will generally be of the shape known as a Quetelet's curve.

It will, apparently, then be a simple matter to calculate the prolificacy of the progeny of any plant whose history is known ; and to select as might be desired for either high or low prolificacy.

But unfortunately this is not possible ; we have overlooked the phenomenon referred to as prepotency, or that some individuals are said to have a higher heredity coefficient than others.

An Explanation of "Prepotency."

The quantitative physical manifestation of any character may be regarded as a composite of an inherent or germinal factor, which is inherited, and the environmental factors which as they do not affect the gametes cannot be transmitted to the progeny. I take for granted that acquired characters are not transmissible.

Thus we cannot directly observe the Mendelian factor of tallness in a pea, but the measurable height in inches of the adult plant, and this is determined by the soil and other conditions of growth and by the presence or absence of the unit characters—tallness or dwarfness.

Similarly we cannot measure the character *prolificacy* directly, for it is only one of the factors contributing to the *yield* of the plant.

And so for every inherent or unit character there will be its outward and visible manifestation which alone we can measure or otherwise classify.

Yield—a Function of Prolificacy and Environment.

Although prolificacy is not a single Mendelian unit yet we may express the yield (A) as a function of three factors :—inherent prolificacy (a), maternal environment (b), and external environment (c).

or $A = f(a, b, c.)$

These two latter factors may perhaps be defined in more detail.

The *maternal environment* (b) connotes the food supply obtained from the mother and other conditions surrounding the embryo from the mitosis or fertilization of the ovum and throughout its development into a ripened grain.

Thus the median kernels of the spikelets in an ear of wheat are small and impoverished ; consequently they tend to produce small plants. [A. E. V. Richardson and Heber Green, *Jour. Agr.*, Vic., 1916, p. 140.]

The *external environment* (c) connotes the conditions of temperature and water, air and food supply, &c., and their variation at each stage from the germination of the seed to the harvesting of the crop. In view of the complications usually present, it is useless to speculate on the particular functions involved.

Epistatic or negative factors such as mechanical accidents or attacks of injurious pests should preferably be separately allowed for.

It is probable that whilst $f(b)$ and $f(c)$ may diminish to zero (resulting in the sterility or death of the plant), yet there seems to be a maximum value to which they can attain.

This maximum value will result from the optimum conditions of environment, both maternal and external.

A low yield in any individual case may obviously be due to either (a), (b), or (c) being small, and does not necessarily prove that the plant had a low inherent prolificacy; conversely a high yield does not necessarily indicate a correspondingly high prolificacy.

But on the law of averages we may expect that the higher the yield the greater will be the probability of the plant possessing a high prolificacy.

This explanation seems to be preferable to the practice of allotting to each individual a coefficient of heredity. It is fundamentally simpler to regard Galton's equation as true for all characters and individuals, and to assume that the effects of (*c*) are not transmitted, though the factor (*b*) controls the store of food provided for the germinating seed and therefore may be expected to influence the progeny in the first generation.

The factors (*a*), (*b*), and (*c*) are all undoubtedly complex. It is generally agreed that prolificacy cannot be a Mendelian unit-character, otherwise it would be difficult to explain the fact that the wheat which gives the best yield under dry-farming conditions is less profitable than other varieties in a high rainfall climate.

But in any case the frequency curve of the yield is a composite, and unless we can measure or eliminate the environmental factors we cannot determine the inherent prolificacy and its variation.

Short of their accurate measurement, an approximate elimination should lead to a correspondingly approximate estimate of the degree of prolificacy and its variation.

The Application of Biometric Methods.

In order to solve this problem, which has arisen in our work during the last six years on the "selection" of Federation wheat, some consideration has been given to the methods of Karl Pearson and his school. Though it is said, with some justice, that his work has not been as productive as might have been expected from the amount of brain power expended, yet the selection of wheat in centgener squares seems to be peculiarly suited to the application of these biometric methods.

The distribution curve obtained by plotting the frequencies of the yields in a centgener square of a uniform sample of wheat is usually of the type of a bell-shaped or symmetrical Quetelet's curve.

This indicates that the variations are due to so many causes that none predominate.

Sometimes the graph is skew (we have obtained examples of this form on plotting the results given by certain cross-bred wheats).

If the series observed contains two classes then the graph will obviously be double-headed.

Irregularity will result if a small number of individuals be included. Less than 100 rarely gives a satisfactory graph, but with 300 or more, a smooth curve can always be relied on.

The smoothing is to some extent empirical, and requires some judgment —perhaps it might be called scientific imagination.

Many indeed most, of the centgener squares in 1915 gave curves showing a buttress on the lower side. This suggests a separate c ass, or rather some special epistatic factor which operated on a section of the plants, causing them to tend to form a second mode.

The character of the graph is evidently an important criterion of the quality of the wheat.

The various constants used in Biometric practice serve to describe the curve quantitatively.

While the arithmetic *mean* is generally accepted as giving the best representative value to the whole group of observations, under special circumstances the use of the *median* or of the *modal* value presents certain advantages.

The spread of the curve or the degree of variation shown can be calculated and expressed as the *Average Deviation*, the *Standard Deviation*, the *Deviation Coefficient*, or the *Probable Error*.

The Insufficiency of Biometric Methods.

If we were dealing with Prolificacy (a) itself, then the application of these constants to our data would enable progress to be made rapidly and results to be foretold with precision; but our measurements are of Yield, *i.e.* (A) where $A = f\ (a, b, c)$, and the deviation coefficients of individual plants and the other constants we might calculate are mainly influenced by variations in the environment and not in the prolificacy.

This is so in all ordinary field tests, no matter how carefully they may be conducted.

What then is to be done ?

The answer, I am afraid, must remain incomplete for the present. I can only give a brief account of the directions in which we have been attempting to solve the problem.

Experimental Work.

The above theoretical consideration of fundamental principles has been developed in the hope that it might assist in directing some wheat selection work in which the writer has been associated with Mr. A. E. V. Richardson and the field officers of the research farms of the Agricultural Department of the Victorian Government.

Outline of Work.

This work may be said to have begun in 1912 with the planting of 200 grains from a single plant of a good strain of Federation wheat.

The 200 grains were planted in a straight row at the Rutherglen Experiment Farm and, when harvested, each resultant plant was carefully kept separate, weighed, and measured. The ears yielded by each plant were also weighed.

In the following season, grains from four of the heaviest plants were seeded in four separate rows, whilst other rows were devoted to seeds from the worst plants, and still others to grains from an average mixture of the medium plants.

In 1914 the single nursery rows were replaced by centgener plots or squares, and for the last three years (1915, 1916, and 1917) the process of selecting and planting seed from the best progeny of the best plants has been continued at the Werribee Research Farm.

Simultaneously seed from the medium progeny of the medium plants and from the worst progeny of the worst plants has also been propagated in these centgener squares as a standard of comparison.

Methods of Procedure.

In our endeavour to select the plants of high inherent prolificacy each season we have proceeded along three lines of attack. These may be summarized under the headings (i) Use of Centgener Squares, (ii) Duplication of Test Plots as far as possible, and (iii) Application of the Principle of Pedigree Culture.

(i) *Use of Centgener Squares.*

By an elaboration of the centgener planting system,* first used by Hayes, at Minnesota, U.S.A., we have endeavoured to eliminate, as far as possible, all differences between the external environments of the experimental plants, whether growing in the same square or in neighbouring squares in the same field.

There are many directions in which the environment may vary, and our efforts have been directed chiefly to the following:—

(*a*) *Uniformity of Soil Fertility and of its Water Content.*—An apparently uniform plot is chosen and thoroughly cultivated, as many as fourteen repetitions of ploughing, harrowing, raking, &c., being carried out. In the final cultivations, no horse tread is permitted, so as to avoid this cause of uneven packing or compression of the soil. Artificial watering has only once been resorted to, and then it was necessary in order to save the crop from drought.

(*b*) *Uniformity of Conditions of Germination.*—This is controlled by planting the seed at a uniform depth (¾ inch) in the finely raked soil and covering it with a column of sand to insure aeration and enable the growing plumule to avoid hard lumps or clods of earth.

(*c*) *Uniformity of Volume of Soil available for each Plant.*—The use of a specially designed planting board permits each plant to be placed exactly 4 inches, 5 inches, or 6 inches from its neighbours, according to the size of the board. Around the 100 experimental plants there is a guard ring, in the form of an *outer row* of 44 plants of a similar wheat.

Outside this again two buffer rows of an early wheat, such as King's Early, are planted a week or two later with a Planet Junior planter.

A few plants usually fail to develop in each square, leaving a larger area of soil for their immediate neighbours. This is corrected for by planting an early wheat, such as Indian H, in their places as soon as their failure to germinate is definitely decided.

By these means the differences in the volume of soil, and, therefore, of plant food and water supply available for each plant, are, if not negligible, very much less than with the ordinary methods of cultivation.

(ii) *Duplication of Tests, as far as practicable, with the object of Reducing the Experimental Error Statistically.*

A chemical analysis is usually done in duplicate. This is not to reduce the ordinary error of the method (which is not usually of much consequence), but to detect mistakes.

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* *Jour. Agr.*, Vic., 1916, p. 140.

In agricultural experiments, on the other hand, the error of a single measurement is often greater than the effect we are seeking to determine. Hence the error must be reduced statistically, *i.e.*, by repetitions of the measurement.

It is then also possible to calculate what is the probable experimental error of the result obtained.

It should, indeed, be a *sine qua non* of all agricultural experiments that they should be so designed as to give a result indicating not only the effect of the factor under investigation, but they should also in themselves provide a measure of the experimental error of the work.

An obvious difficulty in the way is that it is expensive and laborious.

There are two further limitations which the wheat-breeder has to face. In the first place, it is unfortunately impossible to grow the same grain more than once; and secondly, an ear of wheat contains a limited number of grains, especially when grown under the semi-arid conditions desirable.

Thus, if we are trying to prove that a heavy grain will yield a bigger plant than a smaller grain which has been taken from the same ear as the heavy grain, it is only possible to grow these two grains once each. A large yield obtained in either case is almost as likely to be due to the difference in soil conditions as to any difference in the original seeds. If, however, we take ten or a hundred large grains and compare the average of their progeny with that from ten or a hundred small grains taken from the same ears, then the variations or errors due to soil conditions are statistically reduced in proportion to the square root of the number of observations.

One example of the results that have been obtained may be quoted.

Eighty heavy grains taken had an average weight of 43·5 milligrams, and yielded 2·86 grammes of ears each on the average, whilst 38 light grains taken from the same heads had an average weight of 27·8 milligrams, and yielded an average of 1·81 grammes of ears each.

The individual results were apparently most erratic, and it was only by considering a large number of cases in this way that any definite conclusion could be drawn from the experiments.

(iii) *By adopting the Principle of Pedigree Culture in order to detect the Plants of High Inherent Prolificacy.*

A plant is not discarded or accepted as valuable until after two generations.

This is the method used with such striking success for sugar beets and for maize.

Bearing in mind that the yield of any given plant is produced by the three factors a, b, and c, then we may expect the effect of c—the external environment—to be eliminated in the first generation; but that b—the maternal factor (as exhibited, for example, in the weight of the grain)—will then be still potent, but that it also will become negligible in the second generation.

Incidentally it may be noted that this consideration indicates that it is unfair to compare the heavy seed of one season with the light seed of another and then draw conclusions as to the relative values of the strains.

RESULTS.

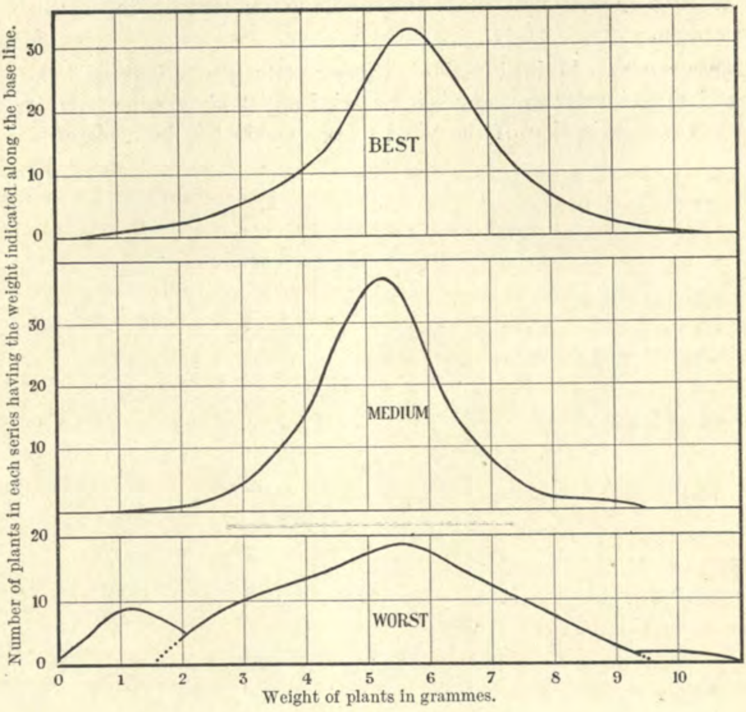
It is too soon to expect to test the value of the methods used, for while our ideal has been the development of a wheat suitable for a semi-arid climate, the seasons have been most erratic, and on only one occasion has what might be described as a normal moderately dry season been experienced.

There have been compensating advantages, however, in these erratic seasons; thus the conditions were so severe in 1914 that in Plot Fd only three plants survived. Of these, number 9 was a giant. This may have been due to the monopoly of food supply it enjoyed, but there was the possibility of its being an inherently prolific mutant. The performance of its progeny supports this view, for it has given rise to a valuable strain.

Again, in 1916 the wet season has enabled us to reject the "unfit" individuals (those which succumbed to the abnormally moist conditions), and those that gave good yields then may be expected to be relatively more robust and resistant to rust, &c. A fair impression of the progress that the selection is making is shown by the frequency charts of the Best, Medium, and Worst wheats.

PLATE III.

GRAPHS SHOWING THE IMPROVEMENT AND DEGENERATION PRODUCED IN WHEAT BY SELECTION IN CENTGENER PLOTS FOR SEVEN YEARS.



The results obtained last year in several centgener plots representative of the Best, Medium, and Worst strains were combined and the numbers of plants in each series having the weights indicated along the base line were plotted in the graph.

In this way we obtain for the Best plots a normal but rather widespread frequency curve with a modal value of about 5·7 grams. There were a fair percentage of plants of very low and also of very high weight—some of these last were utilized for the next season's seed. The average weight of the heads yielded per plant in this section was 1·96 gram.

The three typical Medium plots similarly gave a normal, but more compact, frequency curve of modal value 5·3, whilst the average weight of heads per plant was 1·65 grams. This strain has been obtained by selecting the medium plants of the medium plots for the past six years, and may be considered as fairly well representing the standard of the original seed.

In the last section in which the worst plants have been repeatedly selected each year we obtain a spread out frequency curve with well-marked groups of very poor and very good plants. The modal value is about 5·5, but the average weight of heads is only 1·53.

If we multiply the figures representing the average weights of heads by 10 we get an approximate idea of the yield in bushels per acre to be expected from each of the three strains for the past season.

Thus if we take 16·5 bushels as representing the yield of the Medium —and therefore of the original wheat, selection may be said to have raised this to 19·6 in the Best plots and to have reduced it to 15·3 in the Worst plots.

These results, obtained in the centgener plots, are undoubtedly encouraging, and experiments are now being carried out to determine how far they are a reliable indication of the yield to be expected in bulk plots.

THIRD SESSION, 13th NOVEMBER, 1917.

PRODUCTION OF CEREALS FOR ARID DISTRICTS.

By A. E. V. Richardson, M.A., B.Sc., Agricultural Superintendent, Department of Agriculture, Victoria.

The problem of producing new types of hardy plants suited to arid conditions is of world-wide interest, for each improvement effected enables the margin of cultivation to be extended and new areas to be made subservient to human needs.

Malthus, in 1798, observed that population tended to increase at a greater rate than the increase of food supplies, and forecasted inevitable famine and misery for the greater portion of the race. His prediction was not realized because agricultural development during the past century has more than kept pace with the increase of population. Immense tracts of land in the United States, Canada, South America, and Australia have been opened up, and these provided a large portion of the food to meet the ever-increasing demands of the human family.

Now that there are no new continents to provide foodstuffs for the future increase of the world population, attention must in the future be directed to the better utilization of existing areas under cultivation, and the subjection of those areas which have hitherto been regarded as too arid for profitable culture.

To us the problem assumes more than ordinary importance, for probably no continent has a higher proportion of arid land than Australia. This is shown in Table I., which gives the percentage of area of each continent with a rainfall under 10 inches.

TABLE I.—SHOWING THE AREA OF EACH CONTINENT, AND THE PERCENTAGE OF TOTAL AREA WITH A RAINFALL UNDER 10 INCHES.

Continent.	Total Area of Continent.	Area with Rainfall of 10 Inches or under.	Percentage of Total Area with Rainfall of 10 Inches or under.
	Square Miles.	Square Miles.	%
Asia	16,978,885	5,259,600	31·3
Africa	11,201,439	4,151,400	36·1
North America	8,543,253	1,119,250	13·1
South America	7,423,882	630,850	8·5
Europe	3,860,368	284,900	7·3
Australia	2,974,581	1,105,452	37·0

The physiographic features of Australia are such as to make for arid conditions over a relatively large proportion of its area.

The isohyets of Australia correspond in a general way with the physiographic contours o the continent. So far as the d stribution of rainfall is concerned, the continent may be divided roughly into three approximately equal areas :—

(1) An outer belt of high capacity, with an average rainfall exceeding 20 inches.

(2) An ntermediate belt with an average rainfall of 10–20 nches

(3) An arid interior of low capacity, with a rainfall of less than 10 inches.

Excluding the tropical portion, these areas correspond roughly to (1) the dairying belt, (2) the wheat and sheep belt, 3) the purely pastoral area. These three belts each contain approximately 600 million acres of land.

Agricultural settlement began in the outer belt of highest rainfall, extended graduall y to the ntermediate belt, and is now impinging on the margin of the inner belt.

On the accompanying map of Australia (Plate IV.), the isohyets or lines of equal rainfall have been marked, and the areas of land under cultivation in each of the wheat counties of the Commonwealth have been drawn to scale.

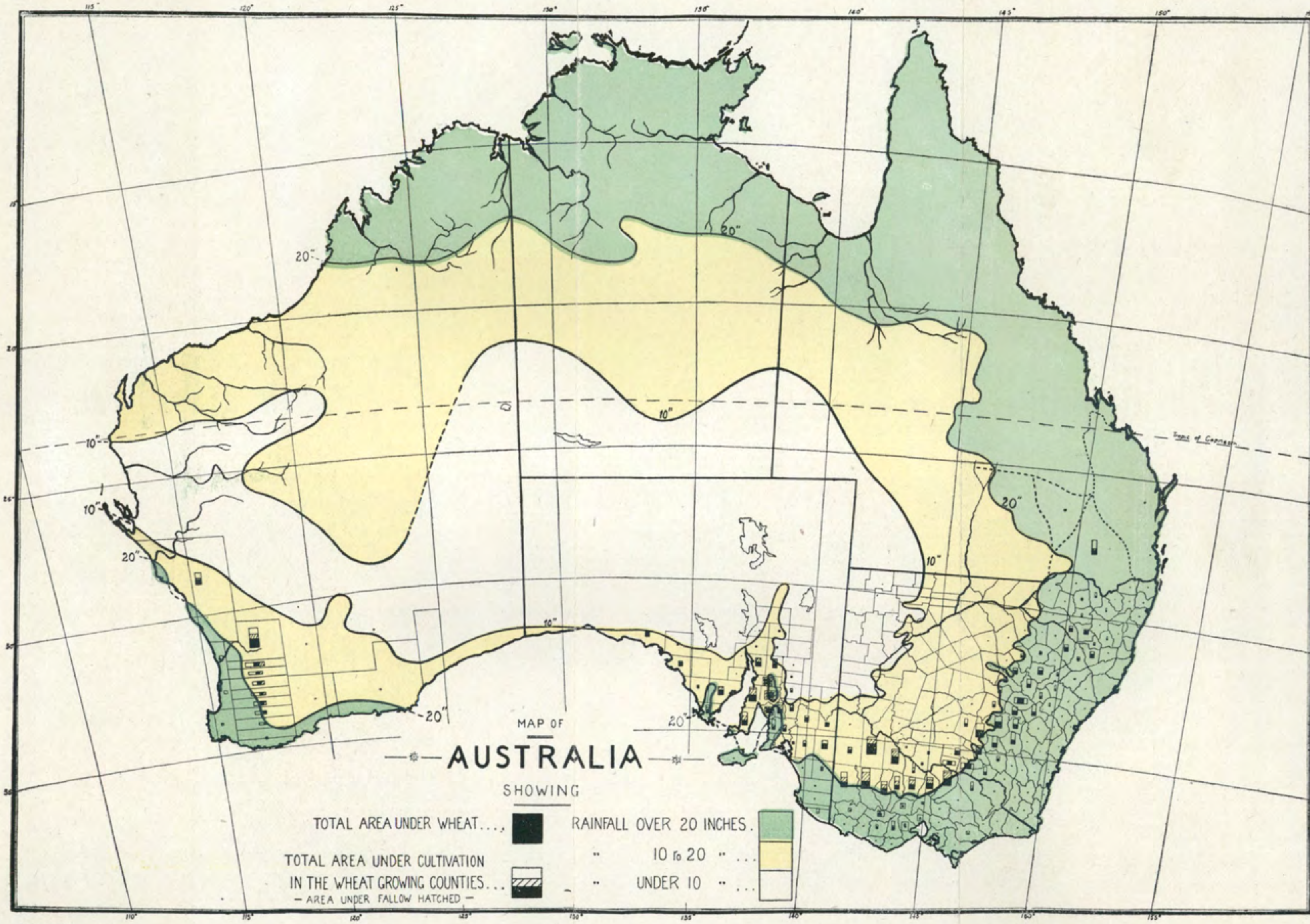
The most striking feature of the map is the vast area of land in the wheat belt await ng systematic exploitation.

The greatest developments in the utilization of arid lands have taken place in South Australia, where the margin of cultivation has been extended beyond the 10-in. isohyet, and profitable wheat cultivation is now carried on in districts with an annual rainfall of less than 10 inches. In Victoria the plough has approached the 10-in. isohyet, but there are still large areas of land in the North-west Mallee which is still in virgin scrub.

In New South Wales, with the exception of the Riverina, the plough has barely passed the 20-in. isohyet. In the four wheat States (New South Wales, Victoria, South Australia, and Western Australia) there are over 200 million acres of land lying between the 10-in. and 20-in. isohyets, of which less than 10 million acres have hitherto been cultivated. There is therefore ample opportunity for expansion before even the 10-in. isohyet is reached. The effectiveness of a rainfall depends upon its incidence and its variability rather than the mere annual average. In Western Australia as much as 85–90 per cent. of the total rain falls between April and October—the growing period of the wheat—when the losses by evaporation from the soil are at a minimum.

As we pass east through the wheat belt the percentage of winter rainfall becomes less, and in Victoria and Southern Riverina about 70–75 per cent. falls in the growing period of the crop. In Northern New South Wales the percentage of winter rainfall is still less than in Victoria. As we approach the inner limits of the wheat belt, the fluctuations in the yearly rainfall are considerable. The annual average of 10 inches may be made up by a few seasons of high rainfall and a number of seasons with a rainfall so low as to make profitable wheat culture impracticable.

With increasing efficiency in cultural methods and the general use of moisture-saving fallows, it is quite certain that the margin of cultivation will be pushed beyond the present limits of cultivation. Throughout the


MAP OF
AUSTRALIA
SHOWING
TOTAL AREA UNDER WHEAT...
TOTAL AREA UNDER CULTIVATION
IN THE WHEAT GROWING COUNTIES...
— AREA UNDER FALLOW HATCHED —
RAINFALL OVER 20 INCHES.
" 10 to 20 " ...
" UNDER 10 " ...
20"
10"
Tropic of Capricorn

C.10404.

wheat belt lands that were considered "unsafe" for farming a decade ago are now producing millions of bushels annually, and the "unsafe" lands of to-day will undoubtedly be the granaries of to-morrow. But, for the fullest utilization of our semi-arid lands, the production of hardy, drought-resistant prolific cereals, suited to the needs of the climate, are essential.

The extension of the margin of cultivation is of the highest economic importance to Australia. For every mile we can push back the boundary of cultivation we add more than a million acres to the wheat belt of Australia.

The Development of the Arid Areas.

Progress in the development of the arid areas will lie along two paths—(1) the improvement of tillage and cultural methods, (2) the production of hardy strains of cereals. While we are specially concerned in this paper with the latter aspect of the problem, we may glance for a moment at the former.

The progress made in improved cultural methods during the past decade has been very gratifying, but many improvements are still possible. These improvements are the more general adoption of bare fallowing, the introduction of a regular system of crop rotation associated with the keeping of sheep, and the wider use of water-soluble phosphates. Though the advantage of moisture-saving fallows as a preparation for wheat is well known, a large percentage of the crop in our drier areas is not sown on bare fallow. The Mallee area of Victoria constitutes the driest portion of the State, with a rainfall of 11-15 inches, yet in 1914 only 24 per cent. of the total area cropped was sown on bare fallow.

This is, of course, partly due to the fact that a considerable area of the Mallee is in process of being cleared, and in pioneer Mallee settlements a large proportion of the land is continuously cropped to rid the land of Mallee shoots; nevertheless a great improvement in yield per acre may be expected when every acre cropped is sown on carefully fallowed land.

Carefully conducted tests at the Longerenong Agricultural College showed that by bare fallowing in a normal season 4·14 inches of rain were conserved by the soil as compared with pasture land. This was almost exactly the amount of water required for transpiration to produce a ton of dry matter—wheat and straw—at the Central Research Farm, Werribee, in 1914. Provided all this moisture could be utilized by the growing crop and none lost by evaporation from the soil, it would mean that every extra inch of water conserved in the soil is capable of producing 3·7 bushels of wheat.

But, of course, under the most perfect system of tillage, some of the conserved moisture must be lost from the soil. At Werribee we found under field conditions that approximately one-third was lost. Even suppose in practice that one-half of the total moisture transpired by the crop was lost by evaporation, each inch would still be capable of producing 2·5 bushels.

It is interesting to note that the average Victorian wheat grower does not obtain more than half this yield in practice. In the *Journal of Agriculture for Victoria*, January, 1916, I showed that there was a close relationship between the composite winter rainfall and the average yield of wheat per acre in Victoria. Thus ten centres representative of the wheat belt of Victoria were taken and the average winter rainfall (May to October) in inches was plotted alongside the figures representing the average wheat yield of the

State. It was found that there was a close parallelism between the two, and that, as an average of 30 years, the farmers reaped as many bushels per acre as there were inches of composite winter rainfall at these ten centres. That is to say, over a 30-year period the composite winter rainfall was approximately 10 inches, and the average yield per acre approximately 10 bushels. Hence the average grower reaped a bushel of wheat for every inch of winter rain received by the crops.

As has been pointed out, the results of transpiration tests at Werribee suggest that the theoretical limit is 2½ bushels for every inch of winter rainfall, allowing for normal losses by evaporation from the soil. Thus it is reasonable to assume that the theoretical maximum yield for a rainfall o 10 inches during the growing period is 25 bushels per acre.

Production of Hardy Cereals.

The limit to the possible conservation of soil moisture will, however, soon be reached. We have, therefore, the other alternative for extending the zone of profitable culture—the production of hardy types of crops suited to arid conditions. In this field of work I think the opportunities ahead of us are almost unlimited. What are the possibilities of producing hardier types of crops, crops that are capable of yielding well under adverse conditions ?

Ability of different Crops to utilize Soil Moisture.

Crops vary greatly in their ability to utilize soil moisture. The first principle to which I wish to draw your attention is the fact that different species of plants vary enormously in their power to utilize soil moisture. The fact that there are considerable variations in the relative water requirements of crops grown under the same soil and climatic conditions is a matter of scientific interest, and great practical importance to a country with a large area of arid land.

The water requirements of various farm crops have been given considerable attention by observers in Europe and America, especially by Lawes (1850) in England, Hellriegel (1883) and Wollny (1886) in Germany, King (1882–5) in U.S.A., Leather (1910–11) in India, Briggs and Shantz (1913–15) in U.S.A., but hitherto no investigations have been recorded in Australia. The results of these investigations show two outstanding facts—(1) That the water requirements, *i.e.*, the amount of water required to produce a unit of dry matter varied with the type of crop. Thus in Briggs and Shantz investigations the crop with the lowest water requirement was millet, whilst lucerne had the highest. (2) That, with the same type of crop there were considerable variations in the water requirement, according to the climatic and soil conditions in which the crops were grown, *e.g.*, to produce a ton of dry matter with wheat in England 235 tons of water were required; in India 554 tons.

What are the water requirements of crops grown under Australian conditions? In order to give information on these matters, a series of tests have been carried out at the State Research Farm, Werribee, and the Rutherg'en Experiment Farm. In 1914 the tests were carried out at Werribee in large pots holding 260 lbs. of soil. Winter grown wheat, summer grown wheat, barley, oats, lucerne, were tested in duplicate, with control plots of bare fallow. The pots were weighed weekly on a steel-yard capable of weighing a load of 300 lbs. and turning to an ounce, and the losses by evaporation and transpiration were made good by the addition of water.

At harvest time the crops were harvested, and the weight of dry matter determined.

The results were as follows :—

TABLE SHOWING TOTAL AMOUNT OF WATER TRANSPIRED, AMOUNT OF DRY MATTER PRODUCED, AND THE TRANSPIRATION RATIO FOR WHEAT, BARLEY, OATS, AND LUCERNE AT WERRIBEE, SEASON 1914.

Crop.	No. Days Growing.	Water used Transpiration and Evaporation.	Water Lost by Evaporation.	Water Transpired by Crop.	Weight of Dry Matter produced.	Grain produced.	Transpiration Ratio for Grain.	Transpiration Ratio for Dry Matter.
		lbs.	lbs.	lbs.	Grams.	Grams.		
Wheat—Federation—								
Pot 2 ..	210	134·5	52·1	82·4	92·75	36·8	1,013	402
Pot 9 ..	210	139·2	52·1	87·1	94·5	37·0	1,065	417
Barley—Cape—								
Pot 5 ..	203	131·8	49·4	82·4	104·26	44·96	712	313
Pot 10 ..	203	150·4	49·4	101·0	126·03	53·28	818	362
Oats—Algerian—								
Pot 6 ..	203	164·1	49·4	114·7	117·88	36·138	1,440	441
Pot 11 ..	203	137·3	49·4	87·9	91·62	35·37	1,124	433
Lucerne—Hunter River—								
Pot 3 ..	365	499·1	84·5	414·6	274·6	..	..	685
Pot 7 ..	365	546·6	83·5	463·1	307·3	..	..	684
Wheat—Federation, Summer grown—								
Pot 4 ..	137	..	..	158·3	99·50	39·75	1,794	716
Pot 12 ..	121	..	..	193·7	136·10	50·60	1,720	641

From this table it will be seen that the average amount of water required to produce a ton of dry matter of the various crops in 1914 was as follows :—

Wheat (Winter grown)	409½ tons
Wheat (Summer grown)	678½ "
Barley (Winter grown)	337½ "
Oats	437½ "
Lucerne	684½ "

An inch of rain falling on one acre is equivalent to 101·28 tons per acre. It follows that to produce a ton of dry matter of each of the above crops, the following quantities of water must have been transpired by the crops :—

Wheat (Winter grown)	4·04 inches of rain
Wheat (Summer grown)	6·69 "
Barley (Winter grown)	3·33 "
Oats	4·31 "
Lucerne	6·71 "

If we consider the amount of water required to produce a unit of grain, the differences between the crops are more marked. To produce one ton of grain per acre, the following quantities would be required to pass through the crop :—

Wheat (Winter grown)	..	1,039 tons, or 10·25 inches per acre.
Wheat (Summer grown)	..	1,757 tons, or 17·34 ,,
Barley (Winter grown)	..	765 tons, or 7·55 ,,
Oats (Winter grown)	..	1,282 tons, or 12·65 ,,

It will be noted that summer grown wheat, although maturing in 74 days less time than winter grown wheat, required approximately 70 per cent. more water than winter grown wheat to elaborate the same quantity of dry matter.

It is worthy of note that the evaporation from a free water surface during the 203 days which the winter grown wheat took to mature was 19·611 inches, whilst the evaporation during the 129 days of the summer grown wheat was 27·566 inches.

These facts explain why wheat growing is possible in regions of light rainfall wherever the greater part of the rain falls in the winter months and the crops are winter grown. Evaporation is at a minimum and the crops produce dry matter with the lowest possible outlay of soil moisture. On the other hand, were the same amount of rain to fall in summer, the losses by evaporation would be much higher, and the crop would require 70–75 per cent. more water to produce the same quantity of dry matter or grain.

These results were obtained by growing the crops in large pots in the field. The crops were subjected to the same atmospheric conditions as the field crops. The tests were conducted in the drought year, and they may be taken as representative of the probable water requirements of the crop in the wheat districts of the State in dry seasons.

The actual amount of water transpired by the crop, however, is not the only factor. Of great practical importance is the amount of moisture lost by evaporation from the soil. In the tests referred to the greatest losses by evaporation were in those plots growing Federation wheat. This was, no doubt, due to the relatively small amount of shade given the soil by the Federation crop as contrasted with the leafy growth of Cape barley and Algerian oats. The loss by evaporation from the soil was 2·52 inches during the growing period of the winter wheat. Consequently the total water used by the winter crop of Federation was 6·62 inches, of which 4·1 was used by the crop and 2·52 lost by evaporation from the soil. On the basis of these figures we may calculate what a crop of Federation wheat might be expected to give if grown in the 10 inch rainfall country.

We have seen that the average rainfall in the growing period ranges from 75 per cent. to 90 per cent. Suppose we place it at 80 per cent, which would give an effective rainfall of 8 inches. Bare fallowing at Longerenong in a dry season conserved 4·14 inches of moisture in the soil. Suppose we take 2 inches as the amount of rain which might be conserved on a 10 inch rainfall by fallowing. This would place an equivalent of 10 inches at the disposal of the crop. This would be sufficient to raise 1½ tons of dry matter—straw and grain. The percentage of grain to total dry matter proved to be 39 per cent. The yield of grain therefore which might be expected on the 10 inch rainfall country is 21·8 bushels per acre.

This may be regarded as the maximum possible in an average season on the 10 inch rainfall country, if we consider the matter purely from the point of view of soil moisture. Such average yield has of course not yet been obtained in any district in the drier country. The average yield of the North-west Mallee of Victoria is about 8 bushels per acre, but many individual farmers, on a similar rainfall, have obtained yields approaching the limits indicated above.

Before leaving the subject of the economy with which different crops utilize soil moisture, I would draw your attention to the comparatively high transpiration efficiency of barley. Cape barley produced dry matter more efficiently than wheat, requiring 3·33 inches of rain for each ton of dry matter produced, as against 4·04 inches for wheat.

In the production of grain, however, it was much more economical than wheat, and required but 7·55 inches to produce a ton of grain, as contrasted with 10·25 inches for wheat.

Barley is not largely grown for grain in the drier areas, but these figures suggest that it has great possibilities as a hardy cereal for arid districts.

Barley has many advantages as a crop for dry districts. It has a short growing period and can be used for green feed, grazing, silage, hay, or grain. Barley hay is very extensively used in the United States, but it must be cut before the flowers are fertilized to make a palatable and nutritious hay.

No export trade in barley has hitherto been possible, consequently the market for barley grain has been very limited. This has been the main reason for comparative neglect. As live stock become more prominently associated with our wheat farms, however, the culture of barley will assume greater importance, both for forage, grazing, and grain. It will usually give twice the yield of wheat if it is given equal cultural treatment.

One of the effects of the war will undoubtedly be greater attention given to the production of stock and the growth of special crops for feeding to stock, both as forage and grain. Barley will be found one of the most useful of crops for this purpose. In the United States, maize is the great food for stock, no less than 2,000,000,000 bushels of this cereal being annually fed to live stock. In Southern Australia the great stock food of the future will probably be barley. So far, however, very little has been done by our plant breeders to develop hardy prolific strains of barley, but there can be no doubt that this is one of the most profitable avenues for future work.

Do wheat varieties differ in their ability to use soil moisture economically? We have seen that different species of cereals exhibit considerable differences in the transpiration ratio. It will now be interesting to find out whether different varieties of wheat vary in their power to utilize water economically.

In 1915 tests were made in the pot culture house at Rutherglen to determine the variations in the water requirements of six different varieties of wheat. The varieties selected were—1, Federation; 2, Dart's Imperial;

3, Yandilla King; 4, Indian 5; 5, Kubanka; 6, Huguenot. Each variety was tested in triplicate. The following table summarizes the results :—

TABLE III.—WATER REQUIREMENTS OF SIX VARIETIES OF WHEAT.
(Rutherglen Experiment Farm, 1915–16.)

Variety.	Species.	Water Transpired and Evaporated.	Water Evaporated from Soil.	Water Transpired by Crop.	Total Dry Matter Grain and Straw.	Dry Matter in Grain.	Transpiration Ratio	Transpiration Ratio for Grain.
		lbs.	lbs.	lbs.	Grms.	Grms.		
Yandilla King	*T. sativum*	55·06	5·24	49·82	108·03	34·21	209	660
Federation ..	,,	64·29	5·24	57·39	111·90	34·54	231	752
Dart's Imperial	,,	67·53	5·24	62·29	123·96	28·81	227	976
Indian 5 ..	*T. compactum*	59·47	5·24	54·23	106·97	33·31	230	740
Huguenot ..	*T. durum* ..	63·29	5·24	58·05	107·08	25·61	243	1,081
Kubanka ..	,, ..	61·33	5·24	56·09	106·52	21·52	238	1,188

It will be seen that the transpiration ratios for crops grown in the pot culture house were much lower than those obtained from crops grown under field conditions at Werribee. This was to be expected for the evaporation from a free water surface in the culture house was much lower than the evaporation under field conditions, and the growth of the crops was far more vigorous under glass than under ordinary field conditions. It was deemed necessary to conduct this experiment under glass in order to gain better control over the crop and reduce evaporation from the soil to a minimum, so as to make the experimental error as small as possible.

Under field conditions, nearly 40 per cent. of the rain or applied water was lost by evaporation from the soil. In the pot culture house, loss from the soil was less than 10 per cent. of the total amount used by the crop.

The results of the tests are striking. It will be noted that the varieties of wheat did not differ much in the quantity of water required to elaborate a unit of dry matter. The most efficient in this regard was Yandilla King, with a transpiration ratio of 209, whilst Huguenot (*T. durum*) showed a ratio of 243. If, however, we consider the water required to produce a unit of grain we find striking differences. While Yandilla King required only 660 tons of water to produce a ton of grain, Kubanka required no less than 1,188, *i.e.*, nearly double.

The Migration Ratio and Early Maturity are Important Factors in Determining the Suitability of Crops for the Arid Areas.

The results of these tests are of importance in the work of evolving types for arid localities. Clearly, one would expect that the types most suited for dry areas would be those which would produce a maximum yield of grain from a unit quantity of soil moisture. Yandilla King, Federation, and Indian 5 showed marked superiority in this respect over either Huguenot or Kubanka. These three varieties all yield a high percentage of grain to straw, averaging 45·3 per cent., whilst the average percentage of grain to straw in Kubanka and Huguenot was but 28·3 per cent.

Since the amount of water required to produce a unit of dry matter is fairly constant for all the varieties tested, it follows that transpiration tests are not necessary to pick out the varieties best suited to arid conditions.

But a most useful criterion is the relative proportion of grain to straw—the migration ratio—for this really is a measure of the efficiency of the plant for utilizing the scanty supplies of soil moisture. Indeed, we will find that in an arid soil a plant makes such adjustments as will enable it to produce as high a ratio of grain to straw as possible.

Consider in this connexion the results of some tests on the transpiration ratio of Dart's Imperial wheat when grown in soils of varying water-holding capacity. At Rutherglen a series of pots were filled with a mixture of loam and river sand to keep at varying degrees of saturation represented by 30 per cent., 45 per cent., 60 per cent., 75 per cent., and 90 per cent. of the water-holding capacity.

The transpiration ratio was determined in respect to each concentration. At harvest the roots of each crop were carefully separated by washing the soil over a sieve in a stream of running water.

The results were as follow :—

TABLE SHOWING EFFECT OF VARYING MOISTURE CONCENTRATION ON THE TRANSPIRATION RATIO.

(Rutherglen Experiment Farm, 1915–16.)

Moisture Content of Soil in Terms of Water-holding Capacity.	Total Dry Matter in Overhead Portion—Grain and Straw.	Total Grain (Grams).	Percentage of Grain to Straw.	Ratio Roots to Overhead Portion.	Transpiration Ratio.	
					For Dry Matter.	For Grain.
%	Grams.		%			
1—30	113·7	32·44	39·9	1 : 9·0	235	823
2—45	131·9	34·24	35·1	1 : 11·1	226	921
3—60	162·9	38·66	31·1	1 : 12·7	257	1,151
4—75	157·3	21·62	15·9	1 : 15·9	259	1,395
5—90	67·3	10·38	18·4	1 : 18·8	302	1,878

From this table it will be seen that—

(1) The maximum yield of dry matter and grain yield was obtained from the pots kept at 60 per cent. saturation, and as the moisture concentration increased or decreased, there was a distinct falling off both in dry matter and grain yield.

(2) The transpiration ratio for dry matter did not vary greatly with the moisture concentration of the soil, except in the soil kept at 90 per cent. saturation.

(3) The transpiration ratio for grain, however, showed a rapid increase as we pass from the low to the high concentration of soil moisture, ranging from 823 to 1878.

(4) The percentage of grain to straw was highest in the pots of lowest moisture concentration, and the percentage rapidly falls as we pass to the higher concentrations.

In soil kept permanently at 30 per cent. of saturation the percentage of grain was 39·9 per cent. of the weight of the straw.

In soil kept permanently at 75 per cent. of saturation the percentage of grain was 15·9 per cent. of the total straw.

Now the wheat grown in these pots was all of the one variety—Dart's Imperial. Obviously the character of the wheat, and particularly the relative proportion of grain to straw varies considerably with the nature of the medium in which it is grown. The conditions obtaining in the pots kept at 30 per cent. of saturation really are comparable with those actually existing in the arid regions, whilst the conditions in the pots kept at the higher moisture concentrations are really comparable with soils enjoying a heavy rainfall.

It will be observed that the arid soils, *i.e.*, the pots of the low concentration (30 per cent. of saturation) produce plants with nearly 40 per cent. of grain to total straw. They also produce a highly developed root system—the dry weight of which was 11 per cent. of the grain and straw produced. On the other hand, the pots of highest moisture concentration produce plants with the lowest percentage of grain (15·9 per cent.), and the least development of roots, the latter forming only 5·3 per cent. of the grain and straw. In the arid soil, therefore, as contrasted with the humid soil, Dart's Imperial wheat produces types of plants characterized by a high percentage of grain to straw, and a relatively large root system.

On the other hand, when grown in humid soils the plants have the minimum percentage of grain to straw, and a poorly developed root system.

Hence we may say that a high migration ratio is the one important factor which is likely to be of use in producing types for arid districts, for this is the factor which determines whether a variety will utilize the scanty supplies of soil moisture wastefully or economically.

Other Important Qualities for Arid Wheats.

This quality of high-migration ratio will, as we have seen, be associated with a well developed root system. It is also most likely to be associated with early-maturing, short-strawed, spare-stooling wheats, possessing narrow leaves, scanty foliage, and small stomata.

Earliness of maturity is of considerable importance, for in most seasons it is essential that the wheat should be well on to maturity before the hot, dry winds of early summer come on. In the majority of seasons there is no certainty of heavy falls of rain in the dry districts after October—the month when the antarctic rains cease. Consequently the crops require to be well on to maturity by the time these rains cease and the hot northerly winds become frequent.

How is the desired variety to be obtained ? If it is in existence it must be isolated and propagated. If not, we must consider whether it is not possible to produce it.

There are three broad lines on which we may work for the production of a variety suited to arid districts.

1. *Acclimatisation.*—The introduction of wheats produced under foreign climes is likely to prove of value in two directions—(*a*) as a direct source of new and useful varieties, (*b*) as an indirect means by cross-breeding, of improving prolific local types with the specific excellence of the introduced type. Bearing in mind the paramount importance of hardy, drought-resistant prolific types for our drier areas, it will readily be seen of what extreme value the introduction of varieties grown for generations in the driest parts of the old world would be. Varieties grown in India, the Mediterranean, Siberia.

Northern Africa, should be especially valuable. Some preparatory period of acclimatisation would, however, be necessary before these varieties might be expected to show up well under Australian conditions, and unless extended trials are given these new varieties they may be prematurely discarded before their real value is discovered.

Much good would be done to place the breeding of hardy cereals on a sound basis, if systematic efforts were made to obtain as large and as representative a collection of cereals—wheat, barley, and oats—from the drier regions of the world as possible, and subject these varieties to systematic tests under the widest possible conditions.

It seems reasonable to suppose that the most rapid way of achieving the ultimate goal is to scour the globe for the most resistant types first, and see how far and to what extent these old world varieties are suitable to Australian conditions. In this direction a Federal organization could do most useful work, organized on lines similar to the Plant Introduction Bureau of the United States, and working in co-operation with the experiment stations of the State Departments of Agriculture.

Some of these varieties would doubtless be of direct use; they would enter into cultivation as soon as their capacity had been demonstrated. But supposing these other varieties we already have in Australia fall short of the requirements; can we make much headway? We can. By the use of selection and cross-breeding on these varieties we may expect to make substantial progress.

2. *Selection.*—Selection enables the breeder to intensify the characters he seeks to improve. He may improve the qualitative or quantitative characters of a plant.

Examples of the former are seen in the increase of the sugar content of the beet, the oil and protein content of corn, &c. As an illustration of the latter, we may take the increase in the length of ear, or the average prolificacy of the variety.

The amount of improvement that may be made in these characters depends on the variability of the plant, and the extent to which the variation is inherited. With qualitative characters the progress that may be made is limited. It has taken nearly a century to raise the sugar content of beets from 7 per cent. to 20 per cent. It took ten years of systematic breeding to raise the protein content of maize at Illinois from 10·92 to 14·2 per cent., *i.e.*, a total increase of 30 per cent. in ten years.

There is, of course, a limit to the extent to which improvement may be made in these characters. In respect to such quantitative characters as prolificacy, which, after all, is the most important property a wheat possesses, there is no doubt that selection can rapidly improve the average prolificacy of a race.

Two broad methods of selection have been adopted—(1) mass selection, (2) individual selection. As an example of the former Zavitz* has shown that mass selection applied to barley and oats over a period of sixteen years raised the average yield of barley from 50 to 63 bushels per acre, an increase of 26 per cent., and of oats from 74 to 100 bushels per acre, an increase of 35 per cent. These improvements correspond closely with the improvements

* Zavitz—Ontario Agricultural College.

effected in the protein content of corn. They are, perhaps, disappointing to those who suppose that material improvement may be expected from systematic selection.

On the other hand, the methods of individual selection have given more rapid and on the whole more satisfactory results. Probably the best examples of these methods are those practised at Svalof (Sweden) by Nillson and his colleagues. The principle involved is to isolate a large number of high-yielding plants, propagate them separately, and determine the value of the various selections by their performances, make use of the principal correlations of agricultural characters with botanical characters, and rapidly multiply those types which are found to be distinctively superior.

Working in Minnesota, Hayes has evolved varieties of cereals which have given increased yields of at least 25 to 30 per cent. over the best local varieties, whilst in Sweden Nillson has by this method been most successful in propagating new prolific varieties suited to the requirements of Sweden.

The practical difficulties are—(1) to make the initial choice, and (2) to eliminate the environmental conditions and throw into relief the genetic characters of the plant.

One must be sure that the chosen plants are really superior and not merely high variants in a population of low mean values. The chosen plants may happen to be superior in appearance because they have received accidental advantages in the struggle for existence. Consequently the testing is even more important than the selection.

One of the most satisfactory methods of testing the selections is the centgener plot, first proposed by Hayes at Minnesota.

This system has for its principle the judging of the value of the selections by the performances rather than by appearance. The centgener plot used was a square plot of plants 12 x 12. The outside row was removed at harvest time, and the yield of the central 100 plants used as the basis for determining the value of the selection. At Werribee we have extended this principle by attempting to eliminate as far as possible the environmental conditions. This has been done by providing (1) that the latter stages of the cultural operations are done by implements drawn by long ropes so as to eliminate the error effect introduced by the consolidation caused by the tramping of horses and men on the plots; (2) that the plots are planted under uniform conditions by mechanical planting devices; (3) that each plant has equality of opportunity in the struggle for existence, for all the plants have the same area of soil to develop in, and they were planted on the same day under identical soil conditions.

At Werribee the centgener plot system has, so far, been confined to isolation of prolific strains of Federation, and to the determination of the inheritance of prolificacy in cross-bred wheats. Federation is the most prolific wheat produced in Australia, and tests are in progress to determine whether it is possible to improve its prolificacy by this method of selection. The tests in progress comprise the following:—

(1) The extent to which fluctuating variation can be inherited within a pure line of Federation wheat.

To determine this each year for the past five years, the best and the worst yielding plants have been compared alongside one another in centgener plots.

(2) To determine the extent to which improvement has taken place by comparing the original seed of 1912 with that produced from the *élite* strains of plants in 1916.

(3) To correlate prolificacy with position of grain in the plant, or to compare the prolificacy of various heads of the same plant and of various grains in the same head.

The individual heads of a plant were weighed and dissected, and the individual grains weighed and planted in the exact order so that the progeny of each may be identified and compared.

(4) To demonstrate whether permanent and real improvement can be made by selection according to the performance in centgener squares, and whether degeneration follows the repeated selection of the worst yielding plants.

Each year the highest and lowest yielding plants, as well as the average plants, are selected to determine whether the mean of the most prolific plants within a pure line could be raised, and whether the mean of the least prolific plants could be lowered by repeated selection.

This centgener plot system is, I consider, the most satisfactory method of testing selections preparatory to their trials in the field. It has certainly great advantages over the nursery row system in reducing experimental error due to environmental influences.

3. *Cross-breeding.*—The third method available for the production of prolific, hardy types is cross-breeding. Great impetus has been given to genetic research during the past 10 years by the re-discovery of Mendel's law of segregation, and many interesting applications of this law have been worked out for the inheritance of unit characters of wheat.

There can now be no doubt that the law which Mendel formulated is one of the greatest of biological discoveries, and his experiments which led to this advance are worthy to rank with those that laid the foundations of the atomic laws of chemistry.

His conception that the plant is built up of unit characters, each of which is independently transmitted in accordance with a definite scheme of inheritance, has placed the subject of plant breeding on a scientific basis. As the applications of Mendel's discovery are extended, it is bound to have a great influence on the breeding of plants. Heredity is the basis of the breeder's work, and any contribution to a more exact knowledge of this subject must prove of service to the art of breeding improved races of plants.

The breeder is ever seeking to improve the type of organisms with which he is working. His final objective is the production of a type which will combine the greatest number of desirable properties with the least number of undesirable ones. His task is to unite these desirable characters in the one variety. The Mendelian conception of unit characters with factors transmitted in accordance with a definite scheme of inheritance must be of great service to him.

Before the breeder can combine the desirable characters into the one individual, he must first determine the inheritance of the characters he is working with. When, however, he has analyzed his material, and the factors upon which the required characters depend have been determined, the production of the required type is rendered easier.

Much work has already been done on the inheritance of botanical characters, such as colour of chaff, density of head, structure of glumes, &c.

At the State Research Farm, Werribee, we have conducted exhaustive investigations over the past five years to determine the mode of inheritance of certain of these botanical characters in wheat and barley. Some of these investigations have involved the classification and segregation of over 20,000 plants.

The following pairs of characters have been found respectively dominant and recessive with—

Wheat—

	Dominant.	*Recessive.*
(1)	Bronze-coloured chaff / Red or bronze coloured chaff	White chaff.
(2)	Baldness..	Beardedness.
(3)	Lax ear ..	Dense ear.
(4)	Woolly chaff	Glabrous chaff.
(5)	Hollow straw	Solid straw.
(6)	Dark endosperm	Starchy endosperm
	(In Spelt types)	(Telfords)
	(In Cedar)	(Clubhead)
(7)	Early maturity	Late maturity.

Barley—

(1)	Baldness	Beardedness.
(2)	Two-rowed ears	Six-rowed ears.
(3)	Black chaff	White chaff.
(4)	Lax ears	Dense ears.
(5)	Hooded awns	Hoodless awns.

Most of the characters so far considered are botanical qualities. The important practical characters requiring investigation are rust resistancy and prolificacy. Biffin has shown that susceptibility to and immunity from yellow rust (*Puccinia glumarum*) behave as a pair of Mendelian characters, and that the production of immune types from prolific but susceptible forms is practicable. This, however, is not the species of rust which causes damage in Australia. The study of the rust problem in Australia from the genetic point of view is complicated by the fact that in some seasons *Puccinia graminis*—the species which causes the greatest damage to crops here—is almost entirely absent from the stud plots. Second generation crossbreds between immune and susceptible types would, under these circumstances, display no obvious segregation, and as immunity is apparently independent of any discernible morphological characters, the detection of the immune and susceptible forms could not be made.

Prolificacy, measured in terms of yield of grain per acre, is the most important quality wheat can possess. Just what factors constitute prolificacy is not definitely known. It is no doubt a complex of several genetic factors, and depends too on the character of the plant's environment.

So far as genetic characters are concerned, prolificacy is probably dependent on the length of the ear, number of spikelets in the ear, number of grains per spikelet, weight of grain, and possibly tillering power.

An effort has been made on the centgener plots at Werribee to determine whether high yielding power and low yielding power are Mendelian characters. The method adopted was to make crosses between a high yielding wheat, such as Federation and Yandilla King, and a low yielding wheat, such as Huguenot. In the second or segregating generation (F^2) the plants were grown in centgener plots, and the grain produced by each plant separately harvested and weighed.

The results were decidedly interesting and suggestive. If the individual weights of these second generation crosses be compared with Federation or Huguenot, we find that while Huguenot and Federation give normal frequency curves, the second generation cross-bred appears to show segregation. The curve for Federation runs parallel to Huguenot, but the average weight of produce is uniformly higher than Huguenot. On the other hand, the curve for the cross-bred is not uniform, but is broken about one-quarter of the way along the line. The curve shows a number of plants as prolific as the best of the Huguenot and Federation, but on the other hand, it also shows a larger number with a much lower yield than Federation. Precisely similar curves were obtained with Huguenot and Yandilla King.

The curves suggest that there is segregation of two distinct groups—one group consisting of high yielding plants, several of which yield more than either of the parent plants, and a second group, forming the greater portion of the cross-breds, consisting of low yielding plants with a mean much below either of the two parents.

Plants taken from the prolific group of plants were sown in centgener plots alongside plants from the non-prolific group. The following were the results :—

Variety.	Huguenot x Federation.	Huguenot x Yandilla King.	Bobs x Federation.	Average of Three Crosses.
	Grams.	Grams.	Grams.	Grams.
1. High-yielding Variants ..	160	138	240	179
2. Low-yielding Variants ..	106	127	197	143

In each case the yield from the plants taken from the high yielding variants gave considerably greater yields in the F^3 generation than the plants taken from the low yielding variants, showing that the differences in yielding capacity were transmitted to the progeny. These experiments are being repeated again this year.

If prolificacy and non-prolificacy were dependent as may be supposed on several factors, then the segregation might be expected to be more complex than the ordinary 1 : 2 : 1 ratio. Moreover, as the only measure of prolificacy is the yielding capacity of the plant, and as experience shows that a considerable variation in yield is observable among the progeny from a pure line, it follows that the detection of segregation into non-prolific and prolific will be a matter of considerable difficulty, and some overlapping is bound to occur.

The centgener method of testing certainly gives the breeder the best possible opportunity to observe such segregation, for fluctuations due to external environment are reduced to a minimum.

Before leaving this subject of prolificacy, one further point should be borne in mind. If we cross two plants which differ in prolificacy, the plants in the second generation produce a family of plants with a range of variation at least equal to that exhibited by the parents, and in addition extreme forms frequently occur which exceed the limits of prolificacy of either parent.

These forms should be isolated and made the starting point of new types. A number of cases of this kind have been observed at Werribee with wheat.

We may take an illustration with barley. A cross-bred barley—a six-rowed bearded type obtained from a cross between skinless six-rowed and a two-rowed bearded—gave a race of plants with a higher migration ratio and a considerably higher yield than either of the parents :—

Variety.	Weight of 100 Plants.	Weight of Grain.	Percentage of of Grain (Migration Ratio).
	Grams.	Grams.	%
Two-rowed Bearded	1,572	368	23
Six-rowed Skinless	1,824	640	35
Cross-bred B6	1,952	824	42

Yield of grain in 5-chain rows, 28 per cent. higher than Cape.

Cross-breeding, I think, holds out brighter prospects than selection for improving our types of wheats, and in producing new prolific types for the drier districts. With selection you cannot anticipate nature. Nature leads, man follows. Nature gives the valuable variation or the mutation, and man merely isolates it and preserves it. He must perforce wait for the variation, and cannot of his own volition originate and produce any distinctively new type by selection. With cross-breeding, however, new combinations may be produced which never existed before. Each character is independently inherited, and the various unit characters may be associated almost entirely at the breeder's will.

To make substantial progress, however, we need to analyze thoroughly our material to determine the unit characters which make up the complexity of the cereal plant, and determine how each character is transmitted in inheritance. Some of that work has been done, *e.g.*, the inheritance of certain botanical characters has been determined. But the more important and difficult part—the determination of the factors which make for prolificacy, rust resistance, milling quality—remain to be determined. Of these prolificacy is by far the most important and most difficult.

This work can be done, but only by the concentration of trained workers working uninterruptedly at the problem for a period of years. Once the material is analyzed, once the mode of inheritance is fully worked out, then plant breeding will be reduced to a more scientific basis, and future work will then yield results of astonishing value to the Commonwealth.

The work of cereal improvement is in its infancy in Australia, and the striking success achieved by Farrer in the work of evolving new and useful types of wheat almost entirely by cross-breeding is extremely encouraging. Milling quality, disease resistance, prolificacy, have been imparted to different varieties in a high degree, but the production of a type combining these qualities yet remains to be done.

The nature of the Australian climate, and the fact that the rainfall rapidly diminishes as we pass from the coast to the interior, makes a study of drought resistance of fundamental importance. With the evolution of hardier strains, new territories may be subjugated and the process of the existing cultivated areas rendered more assured and more certain. The continued testing over as wide and varied a field as possible of approved local and acclimatised foreign types, combined with the systematic breeding from types showing high efficiency in the utilization of transpired soil moisture as measured by the migration ratio, seems to hold out considerable promise for the production of the requisite hardy types.

Summary.

1. The limiting factor in crop production in the drier districts is soil moisture.

2. Those varieties of cereals which utilize soil moisture economically are the types which may be expected to give heavy returns.

3. Experiments show that with any given cereal there is very little difference in the amount of water required to produce a ton of dry matter.

4. There is, however, a wide difference in the amount of grain produced for a given quantity of water.

5. The types which will utilize soil moisture most economically are those which produce a high proportion of grain to straw.

6. High migration ratio and prolificacy under arid conditions are usually associated with short straw, narrow leaves, scanty foliage, and spare stooling powers.

7. The variety, in addition, must be reasonably early, in order to be well on towards maturity before the antarctic rains cease and the hot northerly winds begin.

8. If such types are in existence, they should be isolated and propagated.

9. If not already in cultivation, it is still possible to breed such types.

10. Acclimatisation, selection, cross-breeding, are the three methods available for the production of these types.

11. The arid regions of the globe should be searched for varieties which have been accustomed to grow under arid conditions for centuries. A systematic Plant Introduction Bureau, on the lines of the United States Bureau, would be of great value for Australia.

12. Selection can increase and intensify any desirable quality in a cereal. It cannot, however, originate new forms. It can but take advantage of any variations or mutations which may arise.

13. Cross-breeding is the most powerful instrument man possesses for the modification of plant varieties. It can produce new types by re-combining and re-grouping the unit characters in new forms. It holds out the greatest hope for the plant breeder.

14. The inheritance of many unit characters has already been determined. The mode of inheritance of qualities of the highest practical importance, *e.g.*, prolificacy, resistance to *Puccinia graminis*, and milling quality, have still to be determined.

15. To place plant breeding on a thoroughly scientific basis, the inheritance of these and other undetermined characters must be known. This work should be taken up by a body capable of giving its whole time to research.

Discussion of Papers by Dr. Green and Mr. Richardson.

Prof. Perkins pointed out the value of fundamental experiments, such as those undertaken by Mr. Richardson, since the more we can get to the foundation of things the better chance we have of making progress. The majority, however, were forced to work on empirical lines, and most of the progress made in the past had been made on these lines. Mr. Richardson had given clear proof as to why barley was likely to succeed in drier regions than those where wheat would grow, but in countries where farming had been carried on for centuries this was clearly recognised. He referred to the part of North Africa with which he was familiar and whose climate was, perhaps, more similar to that of Australia than that of any other part of the world. In that country there are three climatic regions: the northern coastal belt, with the highest rainfall, where wheat is grown; a central belt, with lower rainfall, devoted to barley; and a dry belt on the borders of the Sahara Desert, which carries practically only olive-trees. It would be seen that these people recognised the drought-resistant properties of barley, and he believed that the main advantage of barley was due to its capacity of maturing grain within a shorter period than that required for other cereals.

Another matter connected with experience in North Africa was of interest. In that country horses were commonly fed on barley, but when French settlers established themselves there they brought with them the idea that barley was heating and that oats was the proper feed for horses. After years of experience, however, their views had entirely changed, and barley was now recognised as the best food for horses. On his arrival in Australia he had found the same belief prevalent that barley was not such a good feed as oats. He was, therefore, glad to see that Mr. Richardson was advocating barley not only as food for horses, but for pigs, sheep, and in fact all live-stock.

He desired to support Mr. Richardson's remarks as to the desirability of establishing an export trade in barley. He had made inquiries on the subject, and had ascertained that Great Britain absorbed all the surplus six-rowed barley from the Mediterranean region, and also imported from Russia and the United States, the average c.i.f. price at Liverpool being about 2s. 9d. There seemed no reason, therefore, why we should not supply barley to Great Britain, except that the market had not been opened up, and he would await the result of Mr. Richardson's efforts in this direction with much interest.

In conclusion, he wished to refer to the extension of farming into the drier belt. It was quite true that in South Australia they had pushed beyond the 10-in. line, to their sorrow in some cases, but the experience of those who are on the 10-in. line is that they get good crops about every three years when the rainfall is above the average, whilst in intervening years they often get nothing. He hoped, however, that by the breeding of drought-resistant barleys farming in those regions would be placed on a more secure footing.

Mr. McAlpine eulogized the experimental work that was being undertaken by Mr. Richardson at Werribee, and since so much had already been accomplished in so short a time, he thought that in the future Werribee would be almost as famous as Rothamsted. He regretted that Mr. Richardson had not taken rust-resistance into consideration as a factor in influencing prolificacy. He suggested that barley grown in arid regions might be of importance in the future as a source of alcohol.

Mr. Pye thought Mr. Richardson's paper was ample justification for all the expenditure the Government had made at Werribee and the other experimental farms, but he thought that Mr. Richardson should receive more assistance, otherwise his valuable work would take too long to accomplish. Not only should more properly-trained experimentalists be appointed, but when appointed they should be paid more than unskilled labourers. He advocated the establishment of a considerable annual prize to be offered to the farmer who produced the best seed wheat by selection.

Mr. Easterby said that the whole of Australia was indebted to the Victorian Government for the Werribee Research Farm. The figures regarding transpiration and soil-moisture were of much interest to him, as he had carried out much work on similar lines in connexion with sugar-cane.

Prof. Paterson referred first to Dr. Green's paper, and said that he thought it was important that the more theoretical and statistical aspects of the subject should be considered. With regard to prolificacy, it would be absurd to suggest that it could depend on a single factor; it would be impossible to suggest any character of a plant that had not some bearing on prolificacy. Dr. Green's attempt to analyze what constituted prolificacy was interesting, but he did not think it worth while to distinguish between inherent prolificacy and the internal factors influencing it, since we could not eliminate the latter. The centgener method undoubtedly gave the best chance of eliminating the external factors that influenced it. He was not very sanguine as to the value of mathematics when applied to biological problems, and he therefore doubted to what extent they would be useful when applied to the production of improved varieties of wheat.

Referring to Mr. Richardson's paper, he said that it was the most interesting paper on the subject to which he had ever listened, and with the greater part of it he was in entire agreement. He thought it was well to emphasize the caution as to cultivation under a 10-in. rainfall, which was only an average. It was the crops produced in the years when the rainfall was above the average which were mentioned in the immigration pamphlets. The figure of 4 inches given by Mr. Richardson as the amount of rainfall saved by fallowing was, he thought, too low. When observations were carried down to a depth of 6 feet in America, the amount of water saved was found to be from 5½ to 7 inches, and in our dry conditions here he thought it would be well over 4 inches. With regard to transpiration ratios, he thought that the results of experiments required to be carefully considered. It was well-known, for instance, that the transpiration ratio was reduced by fertilizers. In pot-culture experiments, even if no fertilizer was used, the shovelling and sifting of the soil largely increased its fertility, and subsequent addition of fertilizers might give no extra effect, whilst if applied to the same soil in the field they showed a marked effect.

Finally, he wished to make some suggestions as to breeding new varieties of wheat. Since the object was not to prove the Mendelian theory but to produce new varieties, it was unnecessary, in his opinion, to take elaborate notes on each cross. His views had been ridiculed, but he held quite seriously that a great saving in time would be made if each of the twenty best varieties of wheat was crossed with the other nineteen and all the progeny sown together. In the second generation the most promising forms would be picked out and tested by the centgener or other method and it would be ascertained whether the characters were fixed or not. In this way you would multiply your chance of getting a good new wheat several hundredfold.

Prof. Watt said that Mr. Richardson's paper was packed with information gained as the result of experiments of the highest utility to Australia. At every point new problems were opened up, and it was of the utmost importance that trained men should be forthcoming to carry on the lines of work thus suggested, and that such men should be paid more than labourer's wages.

In New South Wales the rainfall was even more erratic than in the other wheat-growing States, and a considerable portion of it fell in the summer months, so that there was little likelihood of cultivation being pushed back to the 10-in. line; at present they were hardly across the 20-in. line. If they could get to anything like the 10-in. line they would have a greater area in New South Wales growing wheat than in any other country in the world.

With reference to plant-breeding, though a great stimulus had been given by the re-discovery of Mendel's laws, he thought that the work of William Farrer had been the main influence in Australia. It had been maintained that if Farrer had known earlier of Mendel's work he would have achieved better results, but when he did learn of them shortly before his death he made no very great change in his methods; as a matter of fact, he was already working unconsciously along the lines which the recognition of Mendel's laws had since shown to be the right ones.

Unfortunately, the characters of most importance in wheat-breeding were not simple Mendelian characters; rust-resistance might be, and it would be a tremendous help if it could be correlated with some definite physical character, but prolificness was obviously the result of a number of factors, and it was also very difficult to measure it satisfactorily. He suggested that the migration-ratio might be the chief factor of prolificacy under ordinary conditions. It had occurred to him that this might be a simple Mendelian factor, but judging from Mr. Richardson's figures this was not the case with barley. He called attention to the fact that two of the best wheats in Australia had a parent in common; Federation and Yandilla King were both derived from crosses with Yandilla, and both had a high transpiration ratio. He did not know whether Yandilla was still in existence or whether it had recently been used in crossing, but it seemed to have had the character of imparting prolificness to the crosses derived from it. Another most important factor was drought-resistance. Work already done had given some sort of measure of drought-resistance, but it should be carried on from year to year with renewed attempts to get as great accuracy as possible.

Mr. Sutton pointed out that even with the extreme care that had been devoted to the centgener tests great variation in the results was still apparent. Under ordinary conditions this variation was so large that he had become somewhat discouraged as to the value of field variety trials.

He referred to the fact that varieties of wheat produced by selection were nearly all giving place to varieties produced by crossing, though in Western Australia two selections—Penny and Gluya's Early—were still regarded as among the best wheats for the wet and dry areas respectively. He had discussed Mendel's Law with the late William Farrer, and knew that he would not have altered his methods in the slightest as a result of its discovery, though it would undoubtedly have made unnecessary the work of his earlier years. He had discovered for himself that the first generation cross exhibited the features of dominance, though he did not use the term, and that the second generation was the one in which segregation occurred—he called it the variable generation. Towards the end of his life, in order to make a short-cut in the endeavour to produce smut-resisting wheats, he practically adopted the plan suggested by Prof. Paterson, and mixed the plants of the variable generation. The method had been followed for some years, but he (Mr. Sutton) had discontinued it because it was impossible to tell whether the plants were really cross-breds.

He emphasized the danger of pushing cultivation beyond the 10-in. line, and stressed the importance of the incidence of the rainfall, instancing a locality in New South Wales where for two years the average rainfall was 20 inches. In one year it was 2 inches, in the other 38 inches.

He did not approve of the method of mass selection since it was impossible by this method to secure varieties absolutely true to character. Emphasis should be laid on the desirability of farmers using seed obtained by the pedigree system.

Dr. Green, in replying, remarked that apparently every country had its own special varieties of wheat which were not known in other countries, but he did not know of any comprehensive account similar to Mr. Richardson's pamphlet on Australian wheats.

Acclimatisation of varieties from other countries apparently consisted of the selection of the individuals or strains existing in those varieties which were most prolific under the new conditions. Whilst crossing two different varieties of wheat may not yield a more prolific strain, it undoubtedly increases the variability, and from among the more prolific individuals a new prolific strain may be selected. Another method of increasing variability was to give a large amount of fertilizers—a method used by florists.

He thought that Prof. Paterson's plan of indiscriminate crossing would be quite impracticable owing to the enormous number of new forms that would be produced and the impossibility of testing them.

Mr. Richardson, in replying, referred to what had been said as to the danger of pushing cultivation beyond the 10-in. line, and the importance of considering the incidence of the rainfall. He had only indicated an ideal to strive for, and there could be no question that whatever agricultural principles held good for the 10-in. line were equally applicable to the 20-in. line. He quite agreed with Mr. Pye that there was an urgent need for adequately-trained men to carry on experimental work. In reference to Prof. Paterson's remarks as to the transpiration ratio, he mentioned an experiment which he had made by growing wheat in a medium poorer than any natural soil. He took Carrum sea-sand and treated it for 24 hours with 20 per cent. hydrochloric acid, subsequently washing it free from all trace of chlorine before using it in the pots. The transpiration ratio was of approximately the same order as in the other experiments, and the yield was, much to his surprise, about 8 or 9 bushels per acre.

He pointed out that Prof. Paterson's proposal for mixed growing of cross-breds would involve an enormous number of characters which would tax the ingenuity of any one to test satisfactorily. At Werribee they did not make such elaborate notes as had been suggested, but they thought it important to determine the mode of inheritance of each character in order that in future work they might know which forms were likely to breed true. When once this is known it is unnecessary to continue taking notes of these characters. He thought that any one engaged in plant-breeding should take an interest in first principles.

IMMUNITY AND INHERITANCE IN PLANTS.

By D. McAlpine.

If we could picture to ourselves a world in which the various plants cultivated by man, either for pleasure or profit, grew in the most luxuriant fashion as well as strong and healthy, in response to proper cultivation and care, and that they were capable of reproducing themselves in all their pristine vigour, then we would be inclined to say that this was the best of all possible worlds—for plants.

But, unfortunately, we all know that disease soon attacks our cultivated crops, particularly if grown extensively, in spite of all our care, and that the seed by which they are reproduced does not always maintain the standard of vigour and prolificacy. Hence it has come about that the agriculturist is engaged in a perpetual struggle with the parasitic foes that threaten his crops, and, as one of our leading growers tersely put it when the Black Spot of the apple and pear menaced the industry, "We must either conquer the Black Spot or the Black Spot will conquer us." There are various directions in which our best scientific efforts may be put forth to overcome this difficulty and minimize this evil, and I know of none more likely to achieve this object than by seeking to render the plants in which we are interested immune to the various diseases which threaten them, and by a study of the laws of inheritance to keep up the vigour of the race of plants, and even improve it.

Hitherto the diseases of plants have been mainly studied with a view to their ultimate control by means of spraying, fumigation, and other devices. But such methods of treatment are only of the nature of a temporary expedient, although necessary at present until replaced by something better; so that when an apple grower, for instance, requires to spray with Bordeaux mixture or lime sulphur wash for Black Spot, with arsenate of lead for codlin moth, and prepared red oil for scale insects all in the same season in order to secure a profitable crop, it is beginning to be felt that the time has arrived when some more permanent and more up-to-date methods should be adopted.

The control of fungus diseases in plants has become a matter of prime necessity wherever crops are grown on a commercial scale, and there are three principal methods of securing this end. First, there is the destruction of the parasite before it enters the host-plant by means of various sprays, which are capable of arresting the development of the fungus, while innocuous to the plant itself. Second, there is the treatment of the plant already diseased in some portion of it. This method of cure is only practicable in rare cases, and is exemplified in the hot-water treatment of the seed for loose smut of wheat (*Ustilago tritici*) and naked smut of barley (*Ustilago nuda*). In this way the mycelium latent in the seed is destroyed, and it is also found that a dry heat kills the mycelium of potato blight (*Phytophthora infestans*) in the tuber without injuring its vitality. Third, there is the growing of varieties which resist disease, or rendering those varieties subject to disease immune. This method appeals to every grower, and it is the duty of the scientist to meet his wishes, as far as possible, although comparatively little has hitherto been done in this direction.

I thoroughly indorse the view expressed by Luther Burbank, the famous plant breeder, in a letter to me, dated February, 1915: "From your report

I am more than ever convinced of what I have long believed, that all fruit diseases and defects must in the end be *bred out* of them rather than combated in varieties which are susceptible *to* them." It is to the plant breeder, then, we must look for helping us to get rid of many of those diseases which play such havoc in some seasons with our crops.

We have now to discuss immunity, and, at the same time, inheritance, not, however, independent of, but in connexion with, each other. What are the nature and limits of this property of immunity, and how is it to be secured ? Also, what are the laws or principles of inheritance whereby the property of immunity is handed down, like a legacy, for the benefit of future generations of the race of plants possessing it ?

Immunity Illustrated and Defined.

Immunity or resistance to disease may be inborn or acquired, but what is the cause of this immunity or the mechanism of its action has still to be settled. We will confine our attention to immunity in plants, and take as familiar examples the vine disease caused by phylloxera and the wheat disease caused by rust fungi. These represent the two methods which may be used in securing immunity, viz., the grafting of a non-resistant on a resistant variety, or the crossing of a resistant with a non-resistant strain.

The possibility of overcoming disease by means of resistant varieties is well known to the ordinary grower through the phylloxera-resistant stocks introduced into Australia, and has encouraged him to hope that the principle may be extended to other economic plants as well as the vine.

The root-louse, or phylloxera, is a native of America, and was introduced thence into Europe. From time immemorial this insect has preyed upon the native vines of America, but, in course of time, all those types of vine which were severely attacked perished in the struggle for existence, and only those survived which, from their very constitution, were least liable to attack or were practically immune.

Although this insect was introduced into France on vines as early as 1863, it was not discovered until some years later. Then it soon assumed the form of a serious epidemic, and threatened the existence of the vine industry of France. The French naturally turned to America to discover why the phylloxera was not equally destructive in the land of its origin, and they soon learned that the practical immunity of the native vines was the explanation. It was only a matter of time to utilize the wild phylloxera-resistant vine on which to graft the highly-cultivated European vine ; and in Australia, where the phylloxera did immense damage, the vineyards are being reconstructed in a similar manner. The native species best adapted to supply the phylloxera-resistant stocks have now been tested, and hybrids between American wild vines and *Vitis vinifera*, or Franco-Americans, as they are called, have also been obtained, with a resistance which is ample for all practical purposes. As to the efficacy of the immunity, Mr. Francois de Castella, Government Viticulturist, informs me that many of the reconstituted vineyards at Rutherglen have been replanted on the same site where previous vineyards died from phylloxera, yet in no instance has he seen evidence of the slightest damage to the new vines by the insect. Just as in the case of phylloxera resistance, where the host and its parasite have been for a long time in competition, so with the rust in wheat. This disease was well known to the ancient Romans, and, in the course of cultivation, some varieties have succeeded in developing sufficient resistance to survive a severe epidemic. In this way exceptional plants have been found possessing a certain amount of resistance to the disease ; but it is to breeding that we must look for a variety of wheat possessing immunity to rust, and at the same time those desirable qualities which give it a high marketable value. This phase of the question will be dealt with later, in greater detail.

Probable Causes.

As regards the cause or causes of immunity, they probably vary according to the nature of the resistance to be overcome, or the nature of the disease against which the plant is protected.

When a plant is said to be immune, it does not necessarily mean that it is absolutely free from every trace of some particular disease. As in the case of rust in wheat, the parasite may attack the plant, and the spores germinate, and their germ-tubes enter through the stomata. But their further progress is checked, and the resistant tissue of the host-plant does not encourage the growth of the fungus nor the formation of its spores. Hence the plant is practically uninjured, and there is no spreading of infection by means of spores.

Immunity was considered at one time to be due to certain structural peculiarities of the plant possessing it, whereby the parasite was unable to penetrate the tissues. Thus, in the case of wheat, it was thought that the size and hairiness of the flag, the thickness of the cuticle, the size and number of the stomata, &c., might produce the result ; but long-continued experiments have shown that immunity is not dependent on such factors.

There are certain substances in plants, known as *chemotactic*, which have the power of attracting or repelling bacteria and other parasitic organisms. The former are known as positively chemotactic (attractive), and the latter as negatively chemotactic. Massee has stated that immunity is owing to the absence or small proportion of the substances chemotactic or attractive to the parasite in the plant not attacked, and if a plant can be impregnated with some substance which is negatively chemotactic, and at the same time does not affect the usefulness of the plant, then immunity against parasitic fungi might be obtained in this way. Acting on this principle, potatoes susceptible to late blight were grown in pots, to the soil of which sulphate of copper was added. When the tubers were harvested they were found to resist the blight when brought into contact with it.

Cucumber and tomato plants affected with a fungus disease were treated similarly, and they also resisted the disease, even after being sprayed with water containing the spores of the fungus. Cereals were treated for protection against rusts, but without success ; and it is probable that the proper substance was not used to repel the germ-tubes of the rust spores when they attempted to enter the plant.

So far there is no satisfactory explanation of the resistance to disease in one plant and susceptibility to it in another. We can only say that it is in the "constitution" or make-up of the plant that the power of resistance or the want of it lies ; but here we are simply using a word to cover our ignorance.

Diseases exercise a selective influence in weeding out, and immunity is generally regarded as a constitutional variation which has become dominant in the race by the elimination of those members which are not immune.

Predisposition and Immunity.

It is a well-known fact that certain varieties or races of plants are much more liable to contract certain diseases than others, even when grown under similar conditions. And even in a liable variety there may be certain individuals which resist the disease. In short, plants exhibit different degrees of resistance to disease, and this is not only of theoretical interest, but of immense practical importance, for if we can increase the power of resistance to disease we may be able to reach a point where the plant is practically "immune."

This liability or susceptibility or predisposition to disease, as it is now called, is, like immunity, an inborn quality, and therefore inherited. But we must distinguish between the inheritance of a definite disease and of a predisposition to it. So long as the tendency to disease remains passive, and is not stimulated into action, so far the organism is unaffected, and predisposition is just the other side of immunity. While predisposition to disease may thus be inherited, we must also remember that the action of environment, as well as the constitution of the plant, may be necessary to bring out the actual disease.

The late Sir James Paget, in speaking of cancer in ourselves, in his lecture on Elemental Pathology, referred to this concurrence of the internal and external agencies as follows:—"A general tendency to cancer may be inherited, but it must wait till the material of some structure is, by age or injury, or long-continued 'irritation' changed into fitness for concurrence in morbid action with the material on which the general tendency depends. Then, when the two materials meet in mutual fitness, the result may be a change so great that we may compare it with that from an act of impregnation. I have often thought of this comparison when seeing the almost sudden appearance of cancer in breast or tongue, or in a scar long irritated."

Now, whatever be the cause of cancer, it is important for the plant breeder to remember that there may be a concurrence of two materials required, in order to bring about the disease to which the plant is predisposed.

But here we are brought face to face with the most obscure and yet one of the most fascinating problems in the whole range of biology, the inheritance of predisposition and of resistance to disease.

Heredity may be regarded as the phenomenon of the handing on of the parental characters to the offspring, and it may be convenient to speak of the parent as transmitting the characters and of the offspring as inheriting them.

[The lecturer then gave a comprehensive account of modern views of Heredity under the headings: Variation and Inheritance; The Inheritance of Acquired Characters; Inheritance in Pure Lines; Inheritance on Crossing, or Mendelian Inheritance.]

Immunity to Rust in Wheat Inherited.

It will form a fitting sequel to an account of the experiments of Mendel, and a suitable introduction to their practical application, if we take an example of crossing a relatively immune wheat with a susceptible variety.

Biffen, of Cambridge, made a reciprocal cross between a strain of Rivet wheat fairly immune to yellow rust (*Puccinia glumarum*) and a very susceptible Red King wheat. The result of the cross was that all the plants were badly rusted.

Of the 260 plants raised in the second generation, after a very severe epidemic of yellow rust, 64 plants were relatively immune and the remaining 196 plants were infected, for the most part badly. The ratio of the immune to the rusted plants is about 1 to 3, so that susceptibility and immunity may be regarded as Mendelian characters, and the quality of susceptibility to rust is the dominant one, that of immunity being recessive. The structural peculiarities of either of the types did not seem to influence immunity, which, as Biffen puts it, " simply depended on the luck of the shuffle." He also made a series of crosses between varieties which were immune to yellow rust, and Michigan Bronze, which was particularly subject to it. The first generation yielded a badly rusted crop. In the second generation, the whole series yielded 1,609 diseased plants and 523 immune, or a ratio of 1 to 3·08. So that even with relatively large numbers, the proportion still holds.

It is evident that before disease-resistant races of wheat can be bred, we must have resistant individual plants to start with. It is well-known that there are different degrees of resistance to the same parasite in the various species of wheat, and it is possible to select those which show resistance along with other desirable qualities. Generally, however, it is preferable to select the disease-resistant individuals from varieties of the same species, since they are more likely to resemble each other in characters of marketable value. If the resistant individuals give yields too small to be profitable, then they can be crossed with prolific varieties, so that the disease-resistance of the one can be combined with the productivity of the other.

To save future disappointment, the testing of resistance to rust should be carried out by carefully conducted experiments. It is not enough that they remain healthy among diseased ones, for that is not absolute proof of resistance, but the supposed resistant plants should be exposed to the fungus causing the disease to which they appear to be resistant.

Practical Applications.

From what we know of immunity and its inheritance on Mendelian lines, we are justified in believing that by means of systematic breeding and selection, a great many of the diseases to which plants are subject might be eliminated. At the same time, it must be remembered that it can only be settled by experiment what characters will prevail in any cross, and in the case of resistance to disease the test of immunity must be rigorously applied.

It will be necessary to have a testing ground, as well as a plant-breeding ground for disease resistance, not only because it is inadvisable to introduce disease among the general experimental plots, but because the success or otherwise of the cross will depend upon its behaviour under conditions favorable to the development of the particular disease being investigated. If, however, any of the breeding stations are suitable for the purpose, they might be utilized for testing as well. For a number of years I was associated with the late Mr. Farrer in testing his cross-breds for rust resistance at one of the rustiest districts in Victoria, namely, on Mr. Goldie's farm at Port Fairy, a seaport town at the mouth of the river Moyne. Generally, the test is best applied when the cross-bred is fixed, but from the nature of the disease, in some instances, it is possible to apply the test in the course of breeding and thus save time. In the Stinking Smut or Bunt of Wheat (*Tilletia tritici*) it is known that the young wheat plant is infected just when it has germinated and the tissues are young and tender. It is only then that the germ-tubes of the conidia are able to gain access to the interior of the plant, and if the tissues have become hardened and stiffened from any cause, they cannot enter. Now, if the seed which is to produce the variable or second generation of new cross-breds is infected with bunt, the plants from the new generation can be selected which are bunt-free, and thus a strain may be propagated immune to bunt.

The plant breeder of the future must thus extend his operations so as to include a *healthy*, as well as a vigorous and prolific plant. Just imagine a wheat like Federation, which has secured the first place for yield, to have the liability to rust bred out of it by crossing with a rust-resistant variety, and the gain to Australia would be immense. But if these two properties are found to be incompatible, then the experiments might throw some light on the cause of this.

In entering upon this comparatively unexplored field, the plant-breeder has a wide variety of diseases to choose from. But since the breeding of the cereals, such as wheat, oats, and barley, has been the main line hitherto followed, and since a study of their diseases from this point of view has already been begun by the late Mr. Farrer, and continued by Mr. Pye, of Dookie, it is evidently desirable to make this the starting point for fresh discoveries. Being annual plants, self-fertilized, and capable of being grown in unlimited quantities for experimental purposes, they are eminently suited for cross-breeding for disease resistance. I would therefore suggest that the Rusts of Cereals be made a special subject of investigation, as in this line alone there is not only the prospect of increasing the yield, but of extending the area of wheat-growing. The success of a business depends on avoiding losses as well as securing profits, and the loss from rust in wheat in some seasons in Australia is very heavy. In the rusty year of 1889 the loss was estimated to be for the whole of Australia not less than two-and-a-half million pounds, and the immediate outcome of this serious loss was the offer of a reward, in 1890, of £10,000 conjointly by the Governments of New South Wales, Victoria, and South Australia for a cure for the disease of rust in wheat. I need hardly say that none of the specifics submitted in reply to this tempting offer were of any avail, and if the money had been devoted to a scientific investigation of the problem, there would undoubtedly have been some hope of success.

I will now proceed to show how immunity to rust is to be secured, along with other desirable qualities.

In Britain, Biffen, of Cambridge, succeeded in raising a rust-resistant wheat which was only immune to yellow rust (*Puccinia glumarum*) and not to the other rusts attacking wheat. Now, fortunately for Australia, we do not possess the yellow rust, and so cannot test this immune cross under our conditions. But by this example we are reminded of a very important principle in breeding, that a plant cannot pass along to its offspring a factor which it did not itself receive in fertilization. One of the parents in this cross was Red King, which is very susceptible to yellow rust, and in the second generation the relatively immune individuals bred true to the character of resisting this rust. Immunity to rust, then, does not imply resistance to every rust attacking the plant, but only to the specific rust concerned in the cross.

In Australia, the rusts of wheat, oats, and barley have been very carefully determined, and are as follows :—

Wheat Rusts.—Summer or Black Rust (*Puccinia graminis f. sp. tritici*).
Spring or Spotting Rust (*Puccinia triticina*).
Oat Rusts.—Summer or Black Rust (*P. graminis f. sp. avenae*).
Crown Rust (*P. lolii avenae*).
Barley Rusts.—Summer or Black Rust (*P. graminis f. sp. secalis*).
Dwarf Brown Rust (*P. simplex*).

Confining our attention now to the black or stem rust, which is undoubtedly the most injurious in Australia, and to the wheat which suffers most severely from its ravages, I would recommend a series of experiments on the following lines :—

(1) To grow pure lines of the best Australian and introduced varieties of wheat under conditions favorable to the development of black or stem rust. All the descendants arising from a single plant by self-fertilization are spoken of as a pure line.

(2) To select individual plants showing the greatest rust-resistance after having been severely tested, to be used as one of the parents in crossing.

It would be necessary to determine the kind of rust present, in order to be certain that it was the black rust.

It would also be advisable to frame a scale in which the relative resistance could be represented by numbers, and opposite each number a term to indicate its value. I would suggest the following scale where 10 points represent immunity :—

Scale of Points.

Immune to Rust	10
Very slight	8
Moderate	6
Bad	4
Very bad	2
Every part affected	0

(3) To cross species and varieties which are very susceptible to black rust, with those which have proved themselves relatively immune. This would involve the study of hybrids of the first, second, and third generation at least. Each of the parents would be planted alongside for comparison.

(4) To test under field conditions and on a large scale, the crosses which have proved most satisfactory for black rust resistance.

I have endeavoured, in the limited time at my disposal for such a large subject, to show what immunity means, not only in itself, but in its bearing upon the increased production of the Commonwealth.

I have also shown that this property of immunity can be inherited and handed down from generation to generation. As a result of the definite practical knowledge we already possess of immunity and inheritance, we should at least see that the diseases which cause such a large annual drain upon our agricultural resources, are being attended to by the plant breeder. Among these, the rusts of cereals offer the most promising field for immediate investigation, and the time is ripe, in my opinion, for attacking the problem in a thorough, that is to say, a scientific manner.

In a comparatively recent bulletin by Mr. Richardson, on "Wheat and its Cultivation," there is a wealth of information on what is being done in the matter of wheat improvement in other parts of the world, as well as in Australia. Wheat breeding in Australia is there shown to be annually adding to our stock of new and improved varieties, and it has received an impetus from the late Mr. Farrer—that patient and retiring genius, as Mr. Richardson truly calls him—which it has never lost. To produce a farmer's wheat, immune to black rust, would be a fitting tribute to his memory.

There are other serious diseases of wheat, such as Take All and Flag Smut, which might well be bred out by means of crossing.

Breeding for immunity from the various diseases to which fruit trees are subject would be much more tedious than that of annual crops such as wheat, but sooner or later it must be attempted.

There is plenty of room in Australia for experiment farms of the Rothamsted type, where the breeding of plants would be specially conducted and continuity in the work assured. The harvest truly is plenteous, but the labourers are few.

Discussion of Mr. McAlpine's Paper.

Mr. Pridham pointed out that whilst rust was a very serious disease in the main wheat-belt, it did not occur every season, whilst take-all and flag-smut were in evidence every year, and caused a considerable amount of loss, of which little notice was taken except when their attacks were unusually severe.

Mr. Quodling stated that experiments on immunity to rust, on the lines suggested by Mr. McAlpine, were being carried out in Queensland, and success was being obtained. He would be glad of opinions as to what stage in the development of the plant should be considered when estimating the amount of infestation with rust. He would also like opinions as to the best rust-resistant variety to take as a foundation for the work. They had been using an American variety, which appeared to be the most resistant in Queensland, and crossing it with other forms.

Mr. Richardson pointed out that there was a possibility that varieties that were rust-resistant in one locality would not prove to be so in other districts. For instance, Australian varieties which were resistant here had been found to be very susceptible to rust in England as compared with English varieties. For some years Australia had been supplying seed wheat to South Africa and other parts of Africa, and Gluya's Early was particularly in demand there, as it proved to be rust-resistant under South African conditions. He suggested that Huguenot and *durum* wheats might be made the starting point of the desired varieties, as they were immune to rust, though not very prolific. He asked whether it would be better to test cross-bred wheats for rust-resistance in a locality where rust was prevalent in the second generation or to wait until they were fixed.

Mr. McAlpine pointed out that wheats might be resistant to one species of rust and not to others, and that the rusts of other countries might be different species, thus accounting for the differences in immunity of Australian wheats there and in Australia. He thought testing should be done in the second generation as well as in later generations.

Mr. Pye mentioned that he had used *durum* wheats as the basis of all his crosses, owing to their high power of resistance to nearly all diseases. He suggested that since infection occurs, at any rate in part, through the stomata, a study of the stomata might throw light on the nature of rust-resistance, though he believed immunity depended on a number of factors. Millions of pounds had been lost to Australia owing to the fact that rust-resistant varieties were not generally grown.

Mr. Sutton pointed out that Farrer's real object was the production of rust-resistant wheats, and he began his work on the lines now being carried out in Queensland. He suggested that the Advisory Council should form an organization to collect information regarding the different varieties of wheat, and to catalogue them on the plan outlined by Mr. McAlpine. Whilst the *durum* varieties were on the whole very resistant to rust, they were not entirely so. He thought Medeah was the most resistant form in New South Wales; Huguenot, in his experience, was not completely rust-resistant. The time of maturity was important in this connexion, early varieties being often rust-escaping rather than rust-resistant. Gluya's Early was certainly not rust-resistant, and in some seasons was covered with the disease, though it generally escaped it owing to its earliness.

Mr. Quodling said that in his experience Cretan was more resistant than either Medeah or Huguenot.

Prof. Perkins said that Gluya's Early was one of the standard wheats of South Australia, and it was, undoubtedly, rust-resistant. It was no earlier than King's Early, yet in seasons when the latter was destroyed by rust, Gluya's showed only occasional spots of rust. He admitted that King's Early sometimes escaped rust, owing to its earliness, but this was not the case with Gluya's, and the experience of it in South Africa confirmed the opinion in Victoria and South Australia that this variety was truly rust-resistant.

Mr. McAlpine, in replying, referring to Mr. Pridham's remarks, said that taking Australia as a whole, the losses from black rust were much greater than those from other fungus diseases, and he thought, therefore, that it should be dealt with first. Probably the investigation of this problem would throw light on resistance to other diseases as well.

THE ACCLIMATISATION OF PLANTS.

By Geo. L. Sutton, Agricultural Commissioner, Western Australia.

In the popular sense all our cultivated plants of farm, vineyard, and orchard have been "acclimatised," for they have been introduced and have gradually become adapted to our local climatic conditions. Many of these, however, have been introduced from climatic conditions almost identical with those which obtain during the growing period of the plant in its new environment.

In a scientific sense such introductions are usually regarded as cases of "naturalization" rather than "acclimatisation," for it has been generally contended that to establish a case of true "acclimatisation" a difference of climate should be involved.

Owing to the infinite variation in Nature, it is not difficult to establish some difference in climate between any two localities, but it is found there is a striking lack of unanimity regarding the magnitude of the climatic difference considered necessary to establish a case of true acclimatisation. There are some writers who maintain that the difference between the old and new conditions should be a substantial one, and Bailey goes so far as to state that at first the new climate should be injurious to the introduced plant. Two cases stated to be those of acclimatisation in this restricted sense are as follow :—

The first is that of the introduction of maize to the northern States of the U.S.A. It is stated that this plant was successfully introduced from the southern to the northern States, and, though still subject to frosts, it has shortened its period of growth quite one-half in order to accommodate itself to the short season, and so escape the earlier frosts of the northern States.

The other instance is that of the introduction of the Hairy Vetch (*V. villosa*) when brought from Europe to the Connecticut Valley in 1904. When first planted only a small proportion of the plants were hardy enough to live through the severe winter. The seeds of the most hardy plants were selected, and the process repeated for several years. The result is the evolution of a variety which is now a production of very considerable economic importance, as it is sown as a cover crop on the tobacco levels, immediately the staple crop is harvested, to prevent loss of soil fertility.

Though these cases are generally regarded as cases of true acclimatisation even according to Bailey's definition, to those familiar with the mixture of distinct types usually found in varieties resulting from mass selection, they will appear as instances of the segregation of what Johannsen calls "genotypes," and their subsequent isolation by selection. The selection thus practised has perpetuated the characters desired, which were originally possessed by the varying individuals of the mixed race of plants. The climate was evidently not injurious to the types isolated, and in the light of recent knowledge it is therefore doubtful whether such are cases which comply with Bailey's definition. Such a definition is, however, considered to be altogether too exclusive, for it will exclude from cases of true acclimatisation that of the adaptation which has taken place in connexion with the introduction of the rape plant (*B. napus*) into the wheat belt of Australia. When the rains are timely, the climatic conditions which prevail in the wheat areas cannot be considered injurious to this plant, yet in its new environment it has become an annual, though in Europe, whence the seed is usually obtained, it is a biennial. Surely this is a case of true acclimatisation

A better definition seems to be that of a writer whose name is unknown. He states—" Biologically considered, acclimatisation is part of the general process of modification of organism by environment. When the conditions of the new home are approximately similar, no fresh changes will be imprinted on the organism, and the survival of the imported form is obviously natural. Such cases are simply those of dispersal generally by human selection and hardly of acclimatisation in the strict sense. At the other extreme the sum of the external forces or natural selection may be predominantly adverse, the consequent changes pathological, the result non-survival. The term acclimatisation should thus be restricted to cases between these two extremes where the plastic organism becomes " actively and passively adapted to the new environment."

I am convinced that by accepting such a definition many of the instances which its author evidently considered cases of dispersal or " naturalization " only will be found on strict investigation to be instances of true acclimatisation, and are those in which the plastic organism has become actively and passively adapted to its new environment.

It is probable that no structural variations will be found between the plants growing under the old and the new conditions; but this will not be the case when they are examined physiologically. An illustration in this connexion is that of plants of any stable variety of wheat grown in two localities even with only a slight variation in their climatic conditions. It is unlikely that the plants grown in one locality will differ morphologically from those grown in the other, but when examined physiologically it will be found that a difference does exist, for it is known that the life processes of the respective sets of plants will have produced fruits differing in their chemical composition. In such an instance the plastic organism has certainly become adapted to its new environment, and it is therefore a case of acclimatisation.

It is believed that additional examples of similar physiological differences are those given by Darwin, viz., of aconitum which becomes innocuous when grown in frigid climates, and of the hemlock which, when transferred from England to Scotland, does not yield the medicinal ingredient conine for which it is usually harvested.

The lack of agreement as to the correct definition of acclimatisation is probably due to the paucity of strict investigation connected with the subject, and especially during recent times, since the rediscovery of Mendel's work and the consequent stimulus given to and thrown upon the solution of genetic problems.

The difference between " acclimatisation " and naturalization is, however, mainly one of degree, and if the definition which is suggested be accepted, it is believed that a strict investigation of the physiological as well as the morphological characters of most cases of survival will be found to be those of true acclimatisation, and the now recognised popular meaning will be also scientifically correct. Be this as it may, for the present purpose it is proposed to accept the popular definition and consider as acclimatised those plants which have been introduced into the Commonwealth and which flourish under their new environment. From an industrial stand-point, it is more important to add the greatest possible number of useful plants to our flora than to determine the precise term by which their successful introduction shall be defined. From a scientific stand-point it is, however, important that such work be systematic and economical.

Australia owes much to the acclimatisation of plants. How great this indebtedness is may be well illustrated by the history of our agricultural development. When the settlement of this continent with white people was commenced in 1788 the prospect of supplying with the products of the soil the 1,000 persons who composed the baby colony could hardly have appeared worse. In this connexion Governor Philip reported in 1790 that no country offered less assistance to the new settler than did this, and that there was then no prospect of feeding the small community under his control with its agricultural products. There were practically no native agricultural products, and on several occasions because of the lack of them the little settlement was on the verge of starvation owing to the delay in the arrival of ships with supplies from India and the Cape.

How vastly different is the position to-day ? Not only does the Commonwealth produce all its own food requirements, but in addition it helps to feed the Motherland with its surplus agricultural crops. The main crop is wheat, and of this crop in 1915–16 there were produced some 3¾ million tons more than were necessary for home consumption.

This great and striking agricultural advance which has taken place during the intervening century and a quarter would not have been possible had it been necessary to depend upon members of our indigenous flora. Valuable as are its native grasses and fodder plants, it is singularly deficient in plants suitable for cultivation by the agriculturalist. The results which have been achieved have only been possible because plants like maize, wheat, sugar-cane, &c., have been introduced and either naturally or with the aid of man have adapted themselves to our special climatic conditions, in other words, these plants have been acclimatised.

The economic value resulting from the acclimatisation of cultivated plants may be gauged from the published statistics relative to the value of the crops produced in the Commonwealth. The latest obtainable are those for the season 1915–16, and disclose the fact that the value of our cultivated and acclimatised plants now amounts to the magnificent sum of approximately £74,000,000 sterling.

In addition to this sum, a very large amount of wealth has also been produced indirectly as the result of the acclimatisation of plants other than the cultivated forms, *e.g.*, rye-grass, prairie-grass, cocksfoot, clover, &c., which have proved so helpful to our dairying industry. A specially interesting instance is that of the introduction of *Paspalum dilatatum* to the northern rivers of New South Wales. The history of this is somewhat as follows :—

In the year 1890 a small packet of *Paspalum dilatatum* was sent by Baron von Mueller to the Department of Agriculture, in New South Wales, in the hope that the grass would succeed better under the sub-tropical conditions in that State than it had hitherto done in Victoria, where it had been tried with but partial success for several years. Baron von Mueller obtained the original seed from South America.

The packet was divided amongst a number of men, Mr. Edwin Seccombe of Wollongbar, New South Wales, receiving about half-an-ounce. Mr. Seccombe was one of the keenest experimenters of that time and had already done much to introduce new economic plants to the Richmond River District.

In 1891 Mr. Seccombe reported that he did not think much of it as it was rather tussocky, but would continue to propagate it. On 19th May, 1892, he said :—" I have only four roots which are now well stooled. They grow right through our dry summer and keep beautifully green."

One year later, 1893, seed was being sold at £1 per lb. To-day, tons of *Paspalum* seed are exported at 5d. per lb.

It would be difficult to exaggerate the economic importance of this introduction, and it should be particularly gratifying to a gathering of this kind that its introduction to the northern rivers was in no sense haphazard, but was the result of the conception of a trained scientific worker (Baron von Mueller), because of his familiarity with its character and climatic requirements.

Though so much has already been achieved in the Commonwealth as the result of plant acclimatisation there is still a wide field to work in. He would indeed be a bold man and a foolish one who would say that every thing that is best in the world's flora has been obtained for our very varying conditions of soil and climate. With the vast empty spaces of the Northern Territory and other vacant areas outside our coastal fringe, and because of the great need there will be for increased production when the war is over, no effort must be spared to secure, if possible, better plants than are already growing there.

Even in our most closely settled areas the possibilities of plant acclimatisation have not been exhausted. Much has been attempted and accomplished with wheat. There is a useful field almost unexplored in connexion with potatoes, barley, rye, oats, millets, sorghums, and other crops, grasses, &c., more or less drought and disease resistant.

It is, however, certain that the easiest ground has been broken first, and that the achievements of the future, though they may equal or even exceed those of the past, will be more hardly won. Because of this, if possible, the methods of the past should be improved and the defects avoided.

Probably the most serious defect of past methods has been the absence of restrictions upon the introduction of undesirable plant aliens. Because of the absence of such a restriction, the Commonwealth is suffering and will continue to suffer, probably for all time, much annual loss, through the spread of Stinkwort, Stinking Roger, St. John's Wort, Star Thistle, and other objectionable immigrants.

A specially striking instance of harmful introduction came under my notice last month at Geraldton, Western Australia. This was a case of the False Caper, *Euphorbia terracini*, locally known as Carnation Weed. Its extremely vigorous growth in the locality referred to is an extraordinary example of acclimatisation. It is entirely covering many acres, and has proved extremely difficult to eradicate, as it grows from shoots and cuttings. It is entirely valueless for fodder as stock absolutely refuse to eat it at any stage of its existence. This weed is recorded as having been introduced into South Australia prior to 1907, and the seed was probably brought in fodder from that State to Western Australia by Inter-State boats.

Fortunately this defect of past methods has already been remedied by the Commonwealth authorities by means of their quarantine regulations, which prohibit the entrance of certain prescribed seeds and plants into the Commonwealth. That such restrictions are necessary and beneficial is shown by personal experience with some seeds recently imported. Seven samples of reputed drought-resisting grasses were obtained from Nigeria. On arrival in Western Australia these were examined by the Government Botanist (Dr. Stoward) who found in every case a considerable amount of impurity and weed matter. Of the seven samples four were not worthy of admission, and but for the botanical examination made, would probably have been the means of several very undesirable plants being introduced. Two of them contained seeds of most objectionable grasses, one a species of *Aristida*. with fruits armed with long rigid awns. The other contained what was probably a *Tribulus* species, which had very spinous fruits.

As in the case of the False Caper (*E. terracini*), already referred to, many undesirable plants have been unintentionally introduced, and but for the Commonwealth restrictions many more would continue to be introduced, not as direct importations, but as impurities of commercial samples of seed or of grain intended for stock purposes. The extent of this danger is indicated by the results of the examinations made in Western Australia by the Government Botanist (Dr. Stoward). He reports—"During a period of about thirteen months ending in July of the present year, 122 samples taken from consignments of imported grain of various bulks, ranging from a few ounces to many hundredweights, were subjected to botanical analysis. The sources from which the grain is obtained are various, but are principally India, Japan, Morocco, Great Britain, France, and the United States of America. The impurities are principally found in seeds from India, Japan, and Morocco.

The importations of grain from India and Japan comprised chiefly hemp, linseed, and millet. The percentage of impurity by weight is generally low or moderate. The number of weed seeds not numerous and not of a serious type, comprising *Brassica nigra* and another *Crucifer*, not completely identifiable, and probably a new introduction. From Morocco are received parcels of canary seed, imported chiefly as bird food. These consignments invariably contain a high percentage of impurity by weight, among which are many of the weeds prohibited by the Commonwealth quarantine regulations, and well-known introductions which are widely dispersed and established in this and other States. In addition, there are invariably present a number of species of which only a partial determination was possible. These almost undoubtedly will include new introductions of undesirable plants whose power of 'naturalization' under our conditions of climate and soil is not doubtful."

The Departments of Agriculture in each State have always taken a leading part in the work of plant introduction, and, though valuable work has been done, it would have been improved had there been co-operation between the various States and one common plan of operations. This Federal gathering is the first step towards remedying this defect. The work has been defective because it has been spasmodic rather than continuous, and because there has been no adequate system of records. In consequence, there is a lack of data regarding many of the introduced plants that have been tried. The successes have furnished their own records; but there is no record of many of the failures. These should be available for the guidance of others to prevent money being wasted trying them again under similar conditions. Some failures have resulted because plants have been tried under unsuitable conditions, for the untrained grower often fails to realize that acclimatisation has its limitations, and that the existence of plants is only possible between certain cardinal extremes, and it is therefore not possible to grow sugar-cane commercially at Kosciusko nor rice in the Wimmera. It is therefore more than probable that under proper—*i.e.*, scientific—direction some of these failures can be transformed into successes.

Farmers and graziers are always interested in, and ready to try, new and alleged valuable introductions, and, as might be expected in an agricultural community, all classes have been interested in the work of introducing new plants. Travellers and other private individuals, as well as nurserymen and seedsmen, have done excellent service, and, in the aggregate, large sums have been spent by private individuals and business houses in this connexion, not always wisely. The defect has been that, though practical, the work has not been systematic, and in consequence many of the supposedly new introductions have been so only in name, and some of the alleged valuable ones have been valuable only to the seller. It is difficult entirely to eliminate these defects, but they can be minimized by the establishment of a central organization which will officially deal with the introduction of new plants.

To summarize, the deficiencies of plant acclimatisation in the past have been—

(1) Until recently there has been no control to prevent the introduction of undesirable plants.

(2) An absence of co-operation between States and of correlation of the work of individuals.

(3) An absence of systematic records.

(4) The work has been empirical rather than systematic, and spasmodic rather than continuous.

The Australian experience in connexion with the acclimatisation of plants is similar to that of U.S.A. prior to the year 1897. It is authoritatively stated that in U.S.A. the work of the early years failed in doing the good of which it was capable because it was not systematic, and because no adequate records were kept.

In 1897 a section of seed and plant introduction was established in connexion with the Bureau of Plant Industry. The work of finding, getting, and importing new seeds and plants was then put on a scientific basis under the control of Messrs. David Fairchild and Adrien J. Pieters.

This organization has agricultural explorers and collectors in the field, and it takes care of every plant sent in and of every seed distributed. It is on a basis of active co-operation with the experiment stations and farmers all over the country. Up to 1904 some 19,000 specimens had been sent in by agricultural explorers, by friends, or by correspondents, and had been placed upon permanent record. The object of the work has been primarily a practical one, and in introducing plants or seeds endeavours have been made to meet some demand of an experiment station or of a plant breeder, or to carry out the idea of some one of the explorers who saw in a foreign plant industry the possibility of its utilization in America. The interest in new plants is so much greater than it was twenty years ago that really valuable suggestive applications from private experimenters cannot be met because of the lack of funds.

One of the most far reaching in its possibilities of all the introductions of the Bureau has been that of the drought-resistant macaroni wheats to districts where all ordinary wheats had previously failed because of insufficient rainfall. This grain, though unknown on the American grain markets in 1897, was grown to such an extent that in 1905 six million bushels were exported from the United States.

Another instance of a different kind was the introduction of the *Solanum commersonii* from the wet lands of Uruguay at the request of a plant breeder, so that he might hybridize it with the common potato to produce disease-resistant varieties.

Just as it was found advisable in the U.S.A. to remodel their old methods and to place the work of plant acclimatisation upon a systematic and scientific basis, so it is equally advisable to remedy the deficiencies of our present methods in the Commonwealth, and, so as to place the work of plant acclimatisation on a similarly sound basis, to adopt in the future methods that are more economical and scientific than those of the past.

This can best be done by means of a Federal organization directing and co-ordinating the work of the States.

It is advocated that a Federal organization to deal with plant acclimatisation be eventually established and be modelled after the plan which has proved so successful in U.S.A.

The aim of such an organization should be—

(1) The introduction of new plants of possible economic value to all parts of the Commonwealth either from other districts or from overseas.

(2) The encouragement of careful and reliable tests by farmers and others of the introduced plants.

(3) The introduction of seeds and plants of special value to the plant breeder.

(4) The keeping of complete records of the introductions and the results obtained from them.

Realizing the need for placing the work of plant introduction on a more systematic basis in their own State, the Western Australian Committee of the Advisory Council of Science and Industry have appointed a sub-committee to deal with the acclimatisation of plants. The Committee consists of the Hon. Walter Kingsmill, M.L.C. (Chairman); Dr. Stoward, Government Botanist, Secretary; Prof. Paterson; and myself.

It was proposed to establish a central receiving and distributing centre, where plants received could be cared for or raised from seed or otherwise either for transplanting or to increase the supply of seed for the various sub-stations throughout the State. It was proposed to secure the co-operation of the State Departments, and to utilize the experiment stations and State nursery and other Government institutions as sub-stations.

Each of the States, however, is interested in this same kind of work, and the work of introducing the seeds and plants is common to all of them. Because of this it would lead to economy of effort and money if the central organization proposed for Western Australia were a Federal rather than a State organization. If under Federal control, the work in all the States could be conducted according to one common policy, and supervised and controlled by one directing brain. There would thus be correlation and co-ordination between the work of all the States and one method of recording and tabulating and publishing results for general information. In other words, the work would be standardized.

If the time is not opportune for establishing the complete organization referred to in order to deal with the work of plant acclimatisation upon the lines of the American Bureau, it is recommended that the work of plant introduction proposed for Western Australia should become Federal in character, and that the work of securing seeds and plants by correspondence and exchange, arranging the trials, and recording results be undertaken by the Advisory Council of Science and Industry.

The adoption of this proposal would entail the appointment of—

(1) A Director of Plant Acclimatisation, and probably
(2) An expert plant propagator.

The last-named officer would not be necessary if satisfactory arrangements were made with the local State authorities to utilize facilities already existing for plant propagation at some public institution, *e.g.*, Botanical Gardens.

The Director, if appointed, could take the initial steps to place the work of plant introduction in all the States upon a more systematic and continuous basis than exists at present. His work would prove extremely valuable in correlating the existing activities of the different State Departments, and the work initiated by him would prepare the way for a later and more complete organization.

So much would depend upon the Director that, in conclusion, a few words regarding the qualifications of the officer suitable for such a post will not be out of place.

He should possess organizing and administrative ability, and have a broad outlook. It is also essential that he should have had a sound scientific training in some branch of science, for the trained intellect is ever the speediest agent to meet an economic need.

Summarized, the position with regard to the acclimatisation of plants is as follows :—

(1) All our cultivated plants of farm, vineyard, and orchard are exotic, and have been acclimatised.
(2) The wealth produced by these plants, and possible only as the result of their acclimatisation, now amounts to £74,000,000 sterling annually.
(3) Much additional wealth is also indirectly due to the acclimatisation of non-cultivated plants because of the value of such to the dairying and other industries.
(4) As in the past so in the future, the acclimatisation of plants may be expected to prove a source of wealth to the community.
(5) Each State is interested in the work, and has done good work in the past ; but there is no co-ordination of effort between the States.
(6) It would lead to economy of labour and money if co-ordination between the States were brought about and if the work for all the States were directed according to one common plan, *i.e.*, standardized.
(7) This result can be achieved, and the deficiencies of past methods minimized as in the U.S.A. by having a Federal organization to direct the work.
(8) It is recommended that such a Federal organization of Plant Acclimatisation be established.

(9) Pending the establishment of the complete organization and as the nucleus of such it is recommended that a Director of Plant Acclimatisation be appointed at once. His duties to be—

(*a*) To secure seeds and plants by correspondence and exchange.

(*b*) To distribute and arrange tests of same throughout the States.

(*c*) To keep records of the results of the tests.

Discussion of Mr. Sutton's Paper.

Mr. Breakwell was in thorough agreement with Mr. Sutton as to the desirability of seed-introduction, and instanced the valuable work that was being done in the United States by the Plant Introduction Bureau. On the strength of their work on the Soudan-grass of South Africa, he had imported a small bag of seed a few years ago, and its cultivation was now being undertaken by farmers in the west of New South Wales. He referred to the danger of introducing plants that might become pests, but pointed out that under the quarantine regulations all seed imported had to be tested, and could be destroyed on the recommendation of the inspectors, who were State officials acting on behalf of the Commonwealth.

The Secretary stated that the Executive Committee of the Advisory Council had had the subject of plant-introduction brought before them by their Western Australian Committee, and had decided to refer the matter to the present Conference for its advice as to the best means that the Federal body could take to deal with the matter.

Mr. McAlpine stated that in the examination of seed at present undertaken, no attention was paid to the possibility that diseases might be introduced, and he instanced a case where lucerne-rust was introduced with lucerne-seed. The spores of this rust were easily recognisable under the microscope, but the Department had passed the seed as clean, without submitting it to microscopic examination.

Mr. Quodling referred to the action of unscrupulous seedsmen who sometimes introduced new plants by advertising some great virtue which they were said to possess, whereas they might prove to be pests. He thought there should be some control in such cases, as well as in the case of the introduction of seed from one State to another. King Island Melilot was introduced to Queensland as a valuable fodder-plant, but had become a menace to the wheat-crops, and the presence of its seeds had resulted in the condemnation of a large quantity of Queensland wheat exported to Japan during the Russo-Japanese war.

Prof. Watt thought that the negative aspect of acclimatisation, the prevention of the introduction of undesirable plants, was quite as important as its positive aspect. The expenditure of a small amount of money in the past might have saved Australia from Bathurst Burr, Lantana, and Prickly Pear. He admitted, however, that it was difficult to foretell what plants might become dangerous weeds, since St. John's Wort, Lantana, Blackberry, and Sweet Briar were not pests in their native countries, being kept down by cultivation.

Mr. Sutton, in replying, said there was great difficulty in dealing with undesirable aliens, because it was impossible to predict what was going to happen when you introduced a plant. Moreover, some plants were useful or undesirable according to circumstances. Cape Weed is a pest in New South Wales, but is welcome as a fodder plant in South Australia. The only possibility seemed to be the creation of a central authority which would keep records of the behaviour of introduced plants, would destroy any that seemed likely to become a menace, and would decide in doubtful cases. Such an authority would naturally also pay close attention to the possibility of the introduction of diseases with the seeds that were introduced.

FOURTH SESSION, 14th NOVEMBER, 1917.

UTILIZATION OF PHOSPHATE DEPOSITS OF AUSTRALIA.

By John W. Paterson, B.Sc., Ph.D., Professor of Agriculture in the University of Western Australia.

Phosphorus is an essential constituent of the food materials which a crop must draw from the soil, and the amount of phosphoric acid removed per acre by average crops is less dependent upon the kind of crop than any other constituent of plant ash. This suggests its vital importance. Phosphorus is an important constituent of the cell nucleus, and there appears to be an intimate relation therefore between phosphate supply and cell division at the points of growth. It is on this account, probably, that seeds must store up relatively large amounts of combined phosphorus, and also that special demands for phosphate are made by crops during the earlier phases of growth. In pot-culture experiments on poor sand, where the various necessary food-materials are omitted in turn in different cultures, it is always the lack of phosphates which soonest makes itself felt.

The importance of providing easily available phosphates to crops and pasture is now felt throughout the civilized world, and the consumption has become enormous. Thus in 1913 the world's production of mineral phosphates —chiefly used in the superphosphate and compound manure trades—amounted to 6,806,507 metric tons; the production of Thomas phosphate similarly was 4,452,821 tons. These figures take no account of bones and guanos which also reached large figures. While phosphates have a world-wide significance, it is certain that in Australia they have even added importance. There are various reasons for this, some of which particularly apply to our drier areas. Thus it is known, as pointed out by Lawes in 1847, and verified by Watt under local conditions, that a supply of easily available phosphate in the early life of the wheat crop greatly stimulates root development, and thus diminishes the effect of partial drought. Again, phosphates hasten ripening, and this fact, along with the timely sowing of early varieties, likewise diminishes the evil effect of a dry season. A third reason why phosphates are specially important in Australia is one which is independent of season or rainfall, and is connected with the composition of the soil. Generally speaking, our soils are exceptionally deficient in phosphoric acid as compared with those of other lands.

The reason why our soils should be typically deficient in phosphoric acid is not clear, but is apparently not to be connected with the rainfall. In America Hilgard observed no characteristic difference as regards phosphoric acid-content between humid and arid regions, and the same result has been apparent in examining a large number of soils from the wet and dry districts of Victoria. In view of the firmness with which phosphoric acid is held in soils, probably no such difference was to be expected.

In judging of a soil from its analysis one generally looks to the "total" phosphoric acid, *i.e.*, the amount which can be extracted by hot, strong mineral acid—usually hydrochloric. This is probably as good information as can be obtained, although it is well to remember that the "total" phosphoric acid thus extracted is often only about one-half of what the soils will yield on breaking up with hydrofluoric. Taking "total" phosphoric in the conventional sense, however, our Australian soils seem to be very badly supplied. Standards of sufficiency have been adopted by various authorities to indicate the minimum content consistent with fertility, and for convenience these may be here stated in parts of phosphoric acid per 100,000 of soil. By common consent soils below 50 parts are classed as poor, from 50 to 100 medium, and soils over 100 normal to good. How do our local soils compare with these figures? In Western Australia out of 237 soils examined by the Government Department rather over 90 per cent. fell below the normal limit of 100 parts, and no less than 74 per cent. failed to reach even half that amount. In Victoria, also, analyses of 186 soils taken from all parts of the State, and viewed by the Department here as typical soils, gave disappointing figures. Of these 186 soils, no less than 85 per cent. fell below the normal content of 100 parts in 100,000, while 49 per cent. failed to reach even half that amount. Hall's ten typical English soils average 98 parts—a figure more than double those of Western Australia, and nearly 60 per cent. better than the Victorian average.

The power of a crop to obtain its necessary phosphates does not depend entirely, however, upon the "total" which the soil contains. A good deal of attention has been given in recent years to the determination of so-called "available" phosphoric acid, which is extracted by cold dilute acids. Various acids of various concentrations have been used, *e.g.*, 1 per cent. citric (Dyer's method), $\frac{N}{5}$ HCl, or HNO_3, $\frac{N}{200}$ HCl, carbonic acid, and others. It is interesting to note that 1 per cent. citric acid extracts more phosphoric acid than does nitric or HCl of equivalent concentration; because, while almost similar solvent action is exercised in the first instance a reverse action sets in, and some of the phosphoric acid extracted is re-adsorbed by the soil, particularly from nitric and hydrochloric acids. It has been suggested that the citric acid, being itself partially adsorbed by the soil, satisfies to some extent the adsorptive capacity of the soil for phosphoric acid, and thus increases the balance of phosphoric acid held in solution by that solvent.

Availability determinations have received much attention, and on that account we may glance briefly at some results from our own soils for which I have collected data from three important districts of Victoria. These comprise 14 soils from the Wimmera, 6 from the Mallee, and 4 from Goulburn Valley. As compared with Hall's ten English soils, which contain on the average 98 parts of total phosphoric acid per 100,000, the Wimmera soils average only 52 parts of total phosphoric acid, the Mallee soils 50, and the Goulburn Valley 68. The figures are low, but when we go on to consider the low availability of their phosphoric acid as determined by Dyer's method, they become depressing. In Hall's soils 19·6 per cent. of the total phosphoric acid was available, but in the Wimmera soils only 15 per cent. came under this category, in the Mallee soils 9 per cent., and in the

Goulburn Valley only 5·3 per cent. It appears, therefore, that not only is our phosphoric acid low in amount, but that this phosphoric acid also has a specially low degree of availability.

It must be stated, however, that the availability test for phosphoric in soils, which has received so much attention, is no sure guide to the results in culture tests, and this is true whatever solvents are employed by the analyst. Thus Pfeiffer (1915) using different phosphates found that the solubility in water saturated with CO_2 did not always correspond with the availability as indicated by cropping experiments. Similarly in America Wheeler found that from three different soils $\frac{N}{5}$ nitric acid extracted 14, 16, and 14 parts of phosphoric acid, but the corresponding turnip yields were 22 tons, 8 tons, and 2 tons. Also, in America, Burlison (1916), experimenting with a variety of crops, found that there was no particular relation between the citric acid soluble phosphate and the availability of those phosphates for plants. Numerous results obtained by the Victorian Department provide a similar experience with our own soils.

This important fact so often demonstrated leads to one conclusion. Absorption of phosphoric acid by plants is not a simple case of solution of soil phosphate by root acidity and subsequent osmosis into the plant as is generally supposed. The problem is more complicated. In a paper which I read in 1913* it was suggested that absorption of any particular phosphate did not depend wholly upon its solubility, but that it also depended upon the existence of a chemical inducement for the phosphate to change into new combinations at the point of absorption into the plant. This suggestion has since been confirmed and amplified in a most interesting series of experiments by E. Truog at the Experiment Station, Wisconsin (Bul. 41, 1916), and these have a direct bearing upon the method of utilizing native deposits of refractory and low-grade phosphates with which we are now more directly concerned.

In these researches Truog conducted pot experiments using a dozen different crops, in order to compare the relative effect of different phosphates upon the crop yield, using superphosphate, ground calcium rock phosphate, and chemically prepared ferrous phosphate, ferric phosphate, tricalcium phosphate, aluminium phosphate, manganous phosphate, and trimagnesium phosphate. In the results he finds that different species of plants showed some marked individual preferences for the different phosphates, and that prepared ferric and aluminium phosphates produced with a few exceptions good growths, and in a few cases better growths than the superphosphate. This had been found by other investigators. In searching for the reasons, however, he breaks new ground. The first step towards utilization of the phosphoric acid is its solution for which the main agents are water and carbonic acid. In some cases the action is largely one of hydrolysis, *e.g.*, on ferric phosphate, in which case the phosphoric acid goes into solution, and there is left a basic phosphate. In other cases the action may be both by hydrolysis and carbonation, and the products formed are both soluble, *e.g.*, on calcium phosphates, in which phosphoric acid and calcium bicarbonate go into solution, and a calcium phosphate possibly more basic is left behind.

* Australian Association for the Advancement of Science.

Solubility of the phosphates, however, was not the only factor which determined the availability of the phosphates, and Mr. Truog makes an interesting and, I think, important application of the theory of mass action and ionic diffusion to the absorption of phosphates by plants. As is well known, most of the naturally occurring phosphates in soils are to be regarded as solid solutions, in which there is no fixed equivalent of acid and base. "Each point of contact," he continues, "or near contact between the absorbing surface of root hairs and difficultly soluble substances may be regarded as a chemical system which strives to attain a point of equilibrium between the liquid and solid phases. In order," and here is an essential point, "that the solubility reaction may continue in any of the cases it is necessary that proportionate amounts of all the soluble products be continually removed. Thus, if a plant is to feed strongly on rock phosphate, both the calcium acid phosphate and calcium bicarbonate must be used in somewhat proportionate amounts." In harmony with this theory Truog finds from his own investigations and those of others that plants containing a relatively high lime content have also a relatively high feeding power for the phosphoric acid of raw rock phosphate. Peas, clover, lucerne, and most of the *Cruciferae* belong to this class; while maize, wheat, oats, &c., have low lime content, and therefore under similar conditions will find a greater difficulty in obtaining the phosphoric ion from raw calcium phosphate. Pfeiffer (1914), experimenting with oats and lupins respectively on raw bone phosphate, found that lupins absorbed more phosphoric acid than oats, and ascribed this to the greater solvent action of the lupins. But, doubtless, Truog's theory of the higher lime requirement of the lupins gives the true explanation of Pfeiffer's results.

The secondary product of solution lime may, however, be removed by other means than by absorption into the plant, and some of these are referred to by Truog. Thus raw calcium phosphate is more active in acid soils, since such acid will remove the calcium carbonate and bicarbonate from solution, and thus make it possible for the solubility reaction to continue. Conversely, on soils rich in lime the dissolved bicarbonate in the soil water would obviously hinder the solution of rock phosphate and limit its availability—a theory which explains the unsatisfactory results commonly obtained from the use of raw calcium phosphate and bone phosphate on soils well supplied with lime.

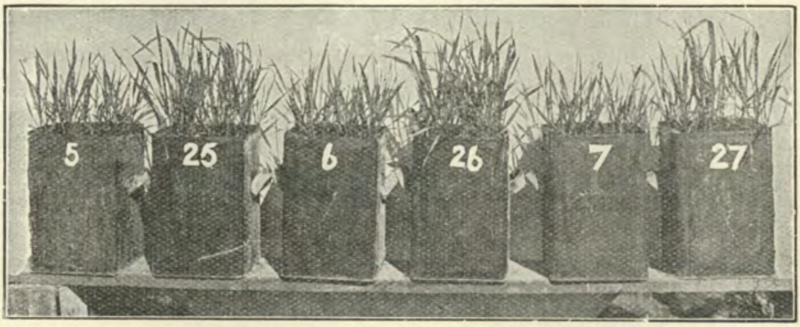
There are many other experiences in manurial trials with crops which could, I think, be explained under the mass action view of soil solution. Thus in dry districts insoluble lime phosphates should be and are less useful to crops than they are under moist conditions, owing to the increased tendency of the carbonate and bicarbonate of lime to remain in contact with the solid phosphate. Again, irrigation increases the absolute amount of phosphoric acid absorbed by a crop—a result which accords well with the mass action theory of phosphate solution, and not with the strength-of-root acidity theory of solution at all. Then again, as is well known, insoluble lime phosphates give better yields when u ed along with ammonium sulphate than with nitrate of soda in culture tests, a result due to the eventual formation of sulphuric and nitric acids from the ammonium salt, these acids destroying the calcium carbonate produced as the phosphate dissolves, and thus opening the path to further solution of phosphate. Nitrate of soda, on the other hand, has eventually a basic action, the resultant soda limiting solution of the phosphate, and consequently the utilization of its phosphoric acid. Finally, the presence of traces of iron salts in solution must powerfully assist the solution of insoluble lime phosphates, because bicarbonate of lime is destroyed by iron salts with the precipitation of ferric hydrate, leaving the way open for further solution of the phosphate. This also agrees with experience that under sufficient rainfall, insoluble lime phosphate, bones, &c., give satisfactory results on ferruginous soils.

So much for insoluble lime phosphates and the increase in their utility resulting from the provision of various means by which their basic constituent can be rapidly removed from action at the scene of solution. Such lime phosphates are all slightly soluble in water, much more so in carbonic acid, and it becomes only a question of removing the products if the solution process is to be continuous. The insoluble phosphates of iron and alumina come into use under the same laws but with differences in detail. These phosphates, especially the basic ferric compounds, have far greater insolubility in dilute acids to begin with, but are much more soluble in dilute alkalies and alkaline carbonates than the lime phosphates, the formation of insoluble hydrate by the alkali no doubt furnishing a chemical motive for their solution.

The results of these differences in solubility between lime phosphates and the iron and alumina combinations cause it to happen that in plant culture tests, while the insoluble lime phosphates act best under potentially acid conditions, the phosphates of iron and alumina work best in soils which are well supplied with lime. Lime, indeed, appears to act as a carrier of phosphoric acid between the undissolved iron phosphate and the plant, a process which is doubtless facilitated by the low solubility of the ferric or aluminium hydrates produced in the decomposition of such phosphates.

It is easy to understand why an application of lime should help the utilization of the natural aluminium and iron phosphates on chemical grounds, and in pot cultures, while the addition of carbonate of lime usually depresses the action of insoluble lime phosphates, it increases in greater or less measure the success of the iron and aluminium compounds. Indeed, the success of these phosphates is largely dependent upon the character of the soil. A curious negligence of the soil factor in an investigation of the effects of different phosphates is shown in some experiments conducted at Rothamsted by Baguley, and reported in the *Journal of Agricultural Science.* Oats, peas, and swedes were grown in prepared white sand in small pots, and 3 per cent. of carbonate of lime, ·5 gram ferric hydrate, and a nutrient solution of potash, nitrates, &c., was added to each pot. The test was between different kinds of phosphates chemically prepared. In the results oats did well throughout on aluminium and also on ferric phosphate, but failed on tricalcium phosphate, the results being no better than in the control series. Even with peas and swedes the results were inferior from the lime phosphate. Had no carbonate of lime accompanied the applications of phosphate it is certain the results would have appeared quite different. Similarly in some pot tests, which I conducted in Melbourne in 1912 along with Mr. Scott, using wheat, an application ot raw calcium phosphate from Ocean Island was markedly superior to aluminium phosphate and also to iron phosphate (Vivianite) in promoting growth where no lime was being used; but in a limed series of pots, using the same phosphates, the iron phosphates became nearly equal, and the aluminium compound was apparently quite equal to the pots receiving phosphate of lime (see Plate V.).

PLATE V.



POT EXPERIMENTS WITH WHEAT (MELBOURNE, 1912).

Soil made up with three of sand to one of clay loam.

Each pot received in common :—

0.5 gram Dried Blood Nitrogen.

0.5 gram K_2O (as Sulphate).

Lime, where given = 45 gram $CaCO_3$ per pot.

The differential manuring supplied 0.3 gram P_2O_5 from various materials.

SCHEME OF MANURING.

	Without Lime.	With Lime.
Calcium Rock Phosphate	Pot 5 ..	Pot 25
Aluminium Phosphate	,, 6 ..	,, 26
Iron Phosphate	,, 7 ..	,, 27

Some field experiments conducted by Wheeler, at Rhode Island, may be quoted as showing the effect of lime upon the more insoluble phosphates in a soil. These experiments were conducted on plots which had each received 82 lbs. of phosphoric acid in various manures per acre up till 1902, and then no further application of phosphates. Nitrogen and potash have subsequently been applied annually to the plots. Lime was applied in 1903 at the rate of 1 ton per acre of slaked lime to certain plots. In 1909, *i.e.*, seven years after the phosphate applications ceased, yields of potatoes were obtained as shown in the table :—

—	With Lime.	Without Lime.	Increase due to Lime.
Diss. Bone Black	680	450	230
Diss. Bone	676	529	147
Superphosphate	554	519	35
Steamed Bone	630	556	74
Thomas Phosphate	592	580	12
Ground Rock Phosphate	505	510	—5
Raw Iron and Al. Phos.	347	244	103
Roasted ditto	594	224	370
Double Superphosphate	607	333	274
No Phosphate	405	145	260

Without lime, seven years after the phosphates were applied, it is seen that no manure still gave the smallest yield, then came the iron and aluminium phosphates, then came roughly those which had been applied in water soluble forms, and finally the best yield from those which had been applied as insoluble lime phosphate. This order of sequence would be expected after the lapse of time, as, owing to reversion and extra removal in previous crops, the originally water-soluble phosphate should leave less phosphate in the calcium combination than, say, bone or Thomas' phosphate. This reversion would be specially prominent with the double superphosphates. When we turn to the limed plots, however, the results are different, and indicate the value of lime in rendering available to the crop phosphates in other combinations than those of calcium, including thereby not only phosphates which had originally been applied as iron or aluminium phosphate, but also those which had reverted to iron and aluminium phosphates from water-soluble combinations. Lime was of little or no advantage on the ground lime phosphate and the Thomas' phosphate, on the limed plots, and the yields from those manures were among the lowest. It had, however, very considerable influence on the phosphates originally applied in water-soluble forms, due no doubt to the fact of these having formed very finely divided iron and aluminium phosphates by reversion within the soil. With the raw iron and aluminium phosphate applied as such, lime had only moderate success in raising the yield; but with the roasted material it had very great effect indeed. The increase from lime on the no-phosphate plot indicates that the phosphoric acid native to the plots existed chiefly in the iron and aluminium combinations, as it will in the great majority of soils. Wisconsin, as the result of analysis, indeed calculates that the ratio of iron and aluminium phosphates to lime phosphates in acid soils may be about 3 : 1; and in soils well supplied with carbonate of lime about 1½ : 1, and the beneficial effect of lime on these yields, in presence of fresh nitrogen and potash applications, is evidence that the native phosphates on the unmanured land were chiefly of the most insoluble kind.

The great manurial need of Australian agriculture is to maintain and increase the supply of available phosphate. At the present time by far the principal manure is superphosphate manufactured almost wholly from rock phosphate from the Ocean and Christmas Islands. In 1913 Australia imported 162,599 tons of natural phosphates.

Native deposits of phosphates occur in most of the States, but those so far discovered are not available for superphosphate manufacture on any large scale. There are two kinds of unsuitable phosphate—(1) calcium phosphates of low grade, (2) iron and aluminium phosphate of any grade.

Regarding the low-grade calcium phosphates it is well known that to make an 18 per cent. superphosphate (about 16 per cent. soluble), you require phosphate of about 34 per cent. phosphoric acid, equal to 76 per cent. tricalcic phosphate. Lower grade superphosphates can be made, of course, from 25 per cent. material, but they are expensive to handle, and if the impurity be carbonate very expensive also in acid.

The presence of much iron and aluminium in a calcium phosphate is of course also most undesirable for superphosphate work, and manufacturers look askance at mineral which contains much over 2 per cent. of iron and alumina. It is said, however, that up to 6 or 7 per cent. is sometimes permissible, provided the calcium phosphate contains much carbonate, which, after treatment, helps to dry the mass by the dehydrating action of calcium sulphate upon the hydrated iron phosphate. With much iron it is usual (1) to grind the mineral finer, (2) use slightly stronger acid, and sometimes (3) to heat the acid before mixing.

Lime phosphate of too low a grade can of course be used in making double superphosphate—whether or not it will pay to do so obviously depends upon commercial and industrial considerations.

Another way of utilizing this class of phosphate is to grind very finely, and use in the raw state upon drained peaty soils under a good rainfall. Such material supplies a useful mixed fertilizer for such lands, when the balance of the material, as is common, consists of calcium carbonate. It would, of course, be of no commercial use in ordinary soils for wheat growing. Owing to its relatively higher solubility in dilute acids, humus will have a better effect on calcium phosphate than on the iron and alumina phosphates.

Iron and Aluminium Phosphates.—Extensive deposits of these occur in several of the States—those of Western Australia apparently consisting chiefly of impure iron phosphates (dufrenite and vivianite), while Victoria has considerable deposits also of an aluminium phosphate. Eight and ten years ago a number of patents were taken out for working these iron phosphates in Western Australia; but to me the proposals seem to have been more or less fantastic in the commercial sense, and certainly none of them has materialized into a working plant. The first consideration in manufacturing from material of this kind is limitation of the cost, the object being to produce a cheap material which can be successfully used, more particularly in increasing the grazing value of pasture lands under a good rainfall.

One feasible means of utilizing the phosphates of iron and alumina would be to smelt them with iron ores, with subsequent separation of the phosphoric acid, as in the manufacture of Thomas' phosphate. Deposits of iron and aluminium phosphates and of low-grade calcium phosphate could be thus employed, and this method is worthy of immediate consideration.

Another less effective but cheaper method would be to burn these phosphates along with limestone in the ordinary way, and subsequently subject the material to fine grinding. There are various facts which suggest the expediency of the method. The solubility of these phosphates is apparently increased by ignition. Thus Fraps (Texas) states that ignition in the case of wavellite and dufrenite greatly increases the solubility of the phosphoric acid in $\frac{N}{5}$ HNO_3. Similarly, Petersen (Wisconsin) found that by heating wavellite for five hours to 200° the solubility of the phosphoric acid increased from 4 to 50 per cent., and heating to 240° increased it 100 per cent.; but dufrenite when heated to 200° was but slightly increased in solubility. The effect of heating upon crop production was evinced in the Rhode Island potato crops above referred to. Lastly, the heating with limestone and subsequent grinding gives an intimate mixture of materials which will favour plant absorption of the contained phosphoric acid, if, as we believe, lime can act as a carrier of phosphate at the point of absorption by the plant root.

Enough has been said, I think, to indicate that the utilization of our more refractory phosphates is not hopeless, but is one worthy of closer investigation. The Advisory Council at my suggestion has decided to investigate the whole matter which will be approached under the three divisions of—

(1) Chemical investigations.
(2) Pot culture tests.
(3) Field experiments.

It is sufficient, in conclusion, to add a few notes upon these subjects in accordance with proposals already submitted to the Council.

Chemical Investigations.—These might concern themselves with—

(*a*) Composition of particular deposits.
(*b*) Solubility of these in acid and alkaline media and in neutral salts.
(*c*) Effect of previous ignition upon the solubility results, having regard to—
  (1) Temperature employed.
  (2) Presence of adventitious constituents in the phosphates.
  (3) Effect of added lime and added silica.
(*d*) Questions arising out of the local manufacture of steel.
(*e*) Analytical control in connexion with the pot and field experiments.

Pot Culture Tests, using, say, oats, clover, and mustard. Soil diluted with about five parts of fresh-water sand. Maintained at two different degrees of moisture, say, 35 and 60 per cent. respectively of total water-holding capacity. Potash and nitrogen to every pot. One series without added lime, the other with 2 per cent. of chalk. Differential manuring to consist of various phosphates used to supply equivalent weights of phosphoric acid and in minimum amounts, viz.:—

(1) Ordinary superphosphate.
(2) Ground rock phosphate.
(3) Pptd. tricalcic phosphate.
(4) Pptd. ferric phosphate.
(5) Pptd. aluminium phosphate.
(6) Raw iron phosphates.
(7) Roasted ditto.
(8) Raw aluminium phosphates.
(9) Roasted ditto.
(10) No phosphate.

Results to be obtained from weight of crops and notes on appearances. Reserve soil in pots after harvesting, and next year mix again with same manures for repeated test.

The above scheme, using ten kinds of phosphate, if carried out in duplicate with three kinds of crop and two degrees of soil moisture, would require

120 pots. In addition, a few extra pots might be set up to test the effect of organic matter added in the form of starch. In these latter tests the nitrogen should be given from time to time during growth in the form of measured dilute solution of nitrate of soda.

Field Experiments.—These should be chiefly confined to permanent pasture, and continue through a series of years. They should be conducted on three different soil types, and under a rainfall of not less than 20 inches—30 inches better. No potash or nitrogen manure used, the object being to discover a cheap and ready means of improving pasture under practical field conditions.

The following dressings are suggested for different plots :—

(1) Superphosphate.

(2) Thomas' phosphate.

(3) Low-grade lime rock phosphate.

(4) Raw iron or aluminium phosphate.

(5) Roasted ditto.

(6) Ditto burnt with limestone.

(7) No phosphate.

The superphosphate could be applied at the rate of 2 cwt. every third year, the Thomas' phosphate in equivalent amount, and the others at double the equivalent amount. Plots of about 5 acres each, and fed with sheep, a small part being fenced off to preserve herbage. Record results annually in respect of (1) stock-carrying capacity, (2) calculated weight of herbage produced per acre, (3) botanical composition of ditto.

The importance of the utilization of our native refractory phosphates on pasture lands hinges on—

(1) The extent of the pastoral country.

(2) The apparent extent of the phosphate deposits.

(3) The very low content of most pasture lands in phosphoric acid.

(4) The limiting effect of low phosphatic content upon the commercial output from pasture lands.

(5) The high price of ordinary phosphatic fertilizer made from imported phosphatic rock.

It is in its pastoral rather than in its purely agricultural industry that Australia holds a special advantage in the world market. In view of the wonderful results of using phosphate upon the wheat crop there is no doubt whatever that the stock-carrying capacity of much of our grazing lands can be more than doubled by suitable applications of phosphate. This can be done by the use of imported phosphates : but for various reasons it is better that local deposits should be used if they can show an equal return for the money. Exact information is required, however, as to whether these can be used, how they can best be used, and what profits are to be expected from their use as compared with imported materials. In view of the very considerable importance of the problems from the point of view of national employment and output, I venture to think that the utilization of our native phosphates is well worthy of systematic investigation.

Discussion of Prof. Paterson's Paper.

Mr Easterby stated that owing to the high percentage of lime in Queensland soils acid manures could not be used to any great extent, and he would be glad of information as to basic superphosphate.

Prof. Paterson said that basic superphosphates were more particularly valuable on acid soils, and, like bonemeal, were found to be active for a longer period than superphosphate on ferruginous formations. On lime soils they had the best conditions for the use of acid phosphates and also of iron phosphates, but not of insoluble lime phosphates.

Prof. Watt said that basic superphosphate was being largely used in New Zealand.

Mr. Richardson emphasized the urgency of finding uses for our local phosphates. There were large deposits of calcium phosphate in South Australia ; one had been opened up at Wellington in New South Wales, and there were large deposits in Victoria of a mixed phosphate, containing 6 per cent. of aluminium phosphate. Since there was more lime than aluminium present, it was incorrect to refer to this as wavellite or aluminium phosphate. It was important to arrive at some conclusion as to the regions in which these phosphates were likely to be used. All trials conducted hitherto had shown that superphosphate was much superior to other phosphates for use in the wheat-belt : this was due to its solubility and to its high divisibility. The Heathcote Chemical Company had a patent for roasting and grinding phosphates. Application of the raw phosphate was little use, but after this treatment the phosphates were of considerable advantage and were becoming popular. He thought, however, that the use of local phosphates would only be satisfactory in districts of high rainfall.

He outlined the experimental work that the Special Committee of the Advisory Council proposed to undertake. The crops to be tested in pot cultures would be lucerne and wheat, and two concentrations of soil moisture would be maintained, 30 to 35 per cent. and 60 to 70 per cent., corresponding to low and high rainfalls respectively. Eight different phosphates would be used, and each would be tested with and without lime.

It had been decided to carry out field-tests at Ballarat, with a 30-in. rainfall, and Leongatha, with a 40-in. rainfall, and in these experiments Wellington phosphate, raw Mansfield phosphate, and the Heathcote Chemical Co.'s roasted phosphate would be used with and without lime.

The chemist of the Heathcote Chemical Co. had suggested a method for treating phosphate so as to produce a small proportion of superphosphate. When a considerable amount of aluminium was present it was impossible to make satisfactory superphosphate, but by heating these phosphates to 800°C., grinding them and using small quantities of acid, it might be possible to make a partial superphosphate.

In experiments conducted by him at Rutherglen some years ago, he had collected grain, stem, and roots of the plants, and had submitted them to analysis, thus obtaining the total amount of phosphoric acid, nitrogen, and potash in the whole plant. Knowing the total amount of moisture taken up during the experiments, it was possible to calculate the concentration of the soil solution. It was found that in the case of phosphoric acid and potash this was approximately constant in all cases. These results were in agreement with those of Cameron and Witney, who had found that no matter what kind of soil was used, the average concentration of the soil solution was six to eight parts per million of phosphate and 25 to 30 parts of potash.

Mr. P. R. Scott, chemist to the Department of Agriculture of Victoria, speaking by invitation of the Chairman, said that the Victorian phosphate deposits were probably neither wavellite nor calcium phosphate. In his opinion they were silico-phosphates, and probably Thomas phosphate was also a silico-phosphate. The Wellington phosphate was of fairly low grade, and was perhaps a gypsum-phosphate. He thought the cave phosphates which had been found in Queensland should be valuable. The utilization of the local iron and aluminium phosphates should, certainly, receive attention; in the past, they had been relegated to the background owing to the ease with which the island calcium phosphates could be obtained. The figures given for the availability of different phosphates depended entirely on the method employed in estimating it; according to the official method, the availability of the Gippsland deposits was 80 per cent.

Dr. Green thought that there was little likelihood of iron phosphate being smelted with lime for the extraction of iron, as suggested by Prof. Paterson. As regards solubility, the length of time the solvent acted was more important than the strength of the solvent; by constantly renewing the solvent, all the phosphate would ultimately be dissolved. The Special Committee of the Advisory Council would take Prof. Paterson's views into careful consideration, but it might be impossible to carry out in its entirety such a comprehensive scheme as he had suggested.

Prof. Watt thought it was doubtful whether local phosphates could ever be used in competition with island phosphates in normal times, though under present circumstances it was obviously desirable, if possible, to liberate the shipping used in bringing phosphates to Australia for other purposes. The ships had, however, been built specially for this trade, and he was doubtful whether they were of much value for ordinary purposes. He thought that if the local phosphates were used at all, it would be on grass-land in districts of high rainfall, and he would like to see the experiments which had been started in Victoria extended to the south-coast district of New South Wales. He had found that the Wellington phosphates were not uniform in composition, and would be unsuitable for the manufacture of superphosphate.

Mr. McAlpine mentioned that he had tried Mansfield phosphates on grass-land in Gippsland, and that it was very beneficial, especially on poor grass-land.

Prof. Perkins said that in South Australia there was practically no permanent pasture-land of any value outside the station country, and in that region the land was of such a low value per acre, and the areas were so great, that it was unlikely that manures would be profitable. Throughout the State it was found that the effect of using superphosphate for wheat was to improve its value for grazing purposes in subsequent years by a very substantial amount.

Mr. Pye said that he had found that superphosphate dressings extended the period during which pastures could be grazed.

Prof. Paterson, in replying, said that it was obvious that it would not be economically sound to manufacture superphosphates from anything but the cheapest materials, but it was still worth while to ascertain whether the local phosphates could be utilized for any purpose, and there was also a possibility that search might reveal rock phosphates in Australia of higher grade than those yet discovered.

It was well known that on the borders of the cultivable area, without an application of superphosphate, the wheat crop would often be a total failure. If this was the case, surely grass-land in the same regions might benefit equally by the addition of phosphates. There was little doubt that the lack of phosphates was the limiting factor in production throughout the greater part of the continent.

THE TOBACCO INDUSTRY IN AUSTRALIA.

By Temple A. J. Smith, Closer Settlement Board, Victoria.

The past history of the tobacco industry in Victoria has been a chequered one for various reasons.

Dating back to the years 1870 to 1888, quite 90 per cent. of the tobacco grown was in the hands of Chinese, who, as growers, left little to be desired They produced large crops, but gave little attention to quality or improved methods of curing. During this period wages were low and land cheap, and the quality of tobacco smoked very inferior to that required by the consumer of the present day. The methods employed in curing the crop were most primitive, the tobacco being dried in open sheds at the mercy of the weather, the result being an inferior leaf, without uniformity of quality, texture, or colour.

From 1888 to 1896 large quantities of this low-grade tobacco were produced, until the market became glutted, and the prices dropped from 6d. and 7d. per lb. to 3d. and 4d. per lb. In fact, it was almost impossible to sell the poorer tobacco leaf at all.

About this time the Victorian Government brought from Virginia, America, a tobacco expert to instruct growers, but, owing to his want of knowledge of local conditions, his efforts were of little value to the industry.

In order to relieve the glut, and at the same time prove the value of the local leaf on the English market, a stemmery was established for the purpose of steaming and stripping the leaf (that is, removing the midrib) and packing the strips in hogsheads for export to England under the management of the American Tobacco Expert, Mr. A. J. Bondurant, assisted by the writer, who had had considerable experience as a grower. In all, about 200 tons were treated and sold to the English and Australian buyers, the growers receiving a bonus of 3d. per lb. on all leaf exported.

Consignments of Victorian tobacco from the stemmery sold in London at from 4d. per lb. to 6½d. per lb., a fair price considering it was a new commodity, and that tobacco buyers are very conservative, and distrust leaf not already proved suitable for their requirements. Heavy grade American leaf of a similar type was selling in England at the same time at 5 cents to 10 cents per lb., or 2½d. to 5d. per lb. On these figures it was apparent that Victorian leaf of a certain quality commanded a fair value, the demand for that class of leaf being, however, much greater in England than in Australia.

Buyers of these shipments were evidently anxious to secure further supplies, as they later cabled to the Victorian Government "regretting no regular shipment of further supplies," thus further emphasizing the fact that the local product was a fair tobacco.

In 1900–2 the surplus tobacco was reduced to a minimum, and Mr. A. J. Bondurant returned to America, leaving the writer in charge of the industry. The amount of leaf produced in this year in Victoria was 35,640 lbs., which amount was gradually increased, with fluctuations due to bad seasons, to 309,629 lbs.

The price gradually increased for Victorian tobacco until 8d. to 9d. per lb. was paid for heavy plug tobacco, and up to 1s. per lb. in special cases for cigar leaf. This improvement in value was due chiefly to the introduction of new and improved varieties imported by the Agricultural Department, which were first proved, and later on the seed distributed free to growers. Better methods of curing were also adopted by a few growers, the majority, however, still growing for quantity, irrespective of quality. In some degree the manufacturers were to blame for this condition of things in not discriminating in regard to better prices for better leaf, and growers have complained bitterly that an all round price has been paid for good, bad, and indifferent leaf, no encouragement being offered to the more careful grower to further improve the quality of his tobacco.

The fact that the purchase of leaf is practically in the hands of one buyer, who operates for the British Australasian Tobacco Company, W. D. Wills and Co., and Dixon and Co., the largest manufacturers in Australia, eliminates competition, and places the growers in the hands of one buyer only. This fact was demonstrated by the evidence given before the Royal Commission of years 1904–5–6, and the Inter-State Commission in 1915.

During the period 1901 to 1917 no further glut has occurred, the manufacturers being eager to purchase all the leaf grown, though their opinions of Australian tobacco as given before the two Commissions were unfavorable as to the quality of the tobacco when compared with American.

A further handicap to Victorian growers has been the trend of public taste for a lighter-quality tobacco, the liking for bright aromatic and cigarette leaf increasing enormously, and the demand for heavy plug tobacco falling off correspondingly.

To illustrate the fact, evidence given before the Inter-State Commission in 1914 went to show that the local production of cigarettes in Australia increased from 710,437,000 (1,623,000 lbs.) in 1909 to 1,211,610,000 (2,767,000 lbs.) in 1913, an increase of 501,183,000 cigarettes in four years. The importations increasing during the same period from 110,000 lbs. to 167,000 lbs.

Australian smokers are said to smoke, as a whole, better tobacco than any people in the world, and, with a view to producing the class of leaf required, the Agricultural Department has carried out experiments in various parts of the State to prove their suitability for the production of a brighter, lighter class of tobacco. In order to do this, fresh varieties of seed had to be imported and tested, and of some 30 varieties 5 have proved likely to meet requirements.

The production of this type of tobacco almost revolutionizes the old system of tobacco growing. Lighter soils are necessary, and special varieties must be used. Those which up to the present show most promise being Spotted Gum, White Stem Orinoco, Hester, Goldfinder, and Yellow Pryor. The soils proved most adaptable for bright leaf are sandy or shaly soils to a depth of 8 to 12 inches overlying a yellow or reddish clay.

The system of curing this class of leaf differs entirely from that adopted in the past. A shed is required, preferably 16 feet by 16 feet by 18 feet to the eaves; this must be built of wood or some non-conductor of heat and smell, it must be lined with some material close enough to exclude all air, and be provided with ventilators at top and bottom so that the humidity and temperature can be regulated.

Furnaces suitable for wood fuel are let into one side of the shed, and 10-in. diameter flues are run round the building close to the ground and 3 feet from the walls. The tobacco is harvested and taken to the shed the same day, and artificial heat at once started and continued for 75 to 80 hours until the tobacco is thoroughly cured. The last season was, unfortunately, the worst ever experienced, and many of the varieties failed altogether, the tobacco which ripened never thoroughly maturing owing to the constant rains and cold changes.

Notwithstanding these drawbacks, leaf was cured for which offers have been received from the Melbourne buyers of from 1s. to 2s. per lb. Moreover, it has been proved that this system of curing will not only produce lemon-bright types of tobacco leaf, but the heavier plug types will also cure much better under a modified system of flue-curing.

Many experiments have been carried out of late years in the improvement of heavy tobaccoes and cigar leaf. In the former case the old varieties, such as the Shoestring, have been eliminated altogether, and newer and better kinds adopted, such as Blue Pryor, Lex, Conqueror, and Orinoco. In cigar leaf the best varieties are Havana, Vuelta, and Comstock.

Constant experiments have also been conducted in the prevention and cure of diseases, the most formidable of which in Victoria is that known as blue mould (*Peronospora hyoscyami*), which attacks the young seedlings in the beds, and in some years makes a clean sweep of destruction.

The best preventive measures are the selection of new sites for seed beds, preferably in high altitudes, the disinfection of the soil with lime and carbolic acid, and drenching the seed beds with formalin solution. As the beds for 10 acres need not be more than 20 yards by 20 yards, such treatments are not expensive or troublesome.

In manurial experiments it has been found that, on the whole, the soils used in Victoria for tobacco are naturally too rich, and that it would be better to use lighter soils, and to manure these chiefly with superphosphate ; lime, also, in some cases would be advantageous.

The effect of superphosphate at the rate of 2 or 3 cwt. per acre is to stimulate early growth and hasten the ripening period, plants so fertilized maturing three weeks earlier than those untreated. Applications of sulphate of potash are also beneficial, but only high-grade potash fertilizers must be used, otherwise the burning quality of the leaf is injured.

The present state of the tobacco industry is serious ; a run of bad seasons for the crop is being experienced, labour, owing to the war, is scarce, and the wages now paid are much higher than previously ; the hours worked are less, and until this year buyers have not apparently realized the value of encouraging the growers to produce better tobacco.

Now, however, it has been arranged that the standard prices will be paid for tobaccoes of certain qualities, and this will put the grower on a more secure footing, and warrant him in spending more money and attention in building up-to-date curing sheds and growing improved tobaccoes.

It has been proved that high-class bright leaf can be produced under favorable circumstances, and can undoubtedly be further improved by flue-curing, and that heavy dark tobaccoes can also be greatly improved in colour and smoking qualities by a modified system of the same artificial treatment.

The prices offered for both these tobaccoes now are from 50 per cent. to 150 per cent. higher than in previous seasons, and should return growers a handsome profit on tobacco, provided the proper systems are followed to produce the class of leaf in demand. The Commonwealth bonus of 2d. per lb. on all leaf sold at 1s. or over per lb. should also prove an inducement to intending growers to try for the higher priced and better quality leaf.

In cigar tobaccoes, experience has shown that Queensland is better suited to produce leaf of finer texture than Victoria, though the flavour of cigar leaf grown in this State is good. Fine texture is very essential, and though there are places in Victoria capable of producing fair cigar leaf, especially if grown under cheese-cloth, as is the practice in many parts of the United States, other tobaccoes will probably prove more profitable at present.

Experiments in fermentation and inoculation of cigar leaf were carried out at some of the factories recently with marked success, and it is curious that manufacturers had not attempted such treatments before. Leaf that had lain in the factories—considered as useless for years—was treated and converted into useful tobacco, while the fermentation of Australian leaf is now regularly followed.

There is no middleman in Australia to buy up and treat cigar leaf, as is the case in America ; the grower is not in a position to do this work, and the manufacturer has been in the habit of buying his leaf from America ready treated, consequently he knew little of such matters.

The future of the tobacco industry in Victoria can be best forwarded by the encouragement of the production of Bright Lemon and Aromatic types of tobacco. These are the tobaccoes which are increasing in public favour every year. The old black plug tobaccoes have practically disappeared, and lighter smokers are demanded generally, and still lighter tobaccoes will be probably required as time progresses. There is ample scope for the production of this kind of tobacco, the most suitable districts being the North-east, along the foothills of the Dividing Range, and in North-eastern Gippsland.

The Northern irrigation areas do not promise well for tobacco, the soil being less suitable, and the constant winds and duststorms being very damaging. The red sandy soils do not produce good quality tobacco.

It is admitted that bright tobaccoes grown in the southern portions of Australia have better colour, aroma, and smoking qualities than those grown in the north ; it is also noticeable that an altitude of 1,000 feet or more is conducive to the right climate for such types.

The present growers will require much tuition and patience to learn the new systems of growing and curing. One fault of the past has been poor cultivation ; a fallow is necessary for tobacco, especially when lighter soils are to be utilized. Proper curing sheds will be required, involving slightly more expenditure, and closer and greater attention will have to be given to the work.

A fair crop can be taken as 1,000 lbs. of cured leaf per acre. Taking this at 1s. 6d. per lb., a return of £75 per acre would be acquired. The cost of growing and curing, interest on sheds and machinery, would not exceed £25 per acre where all labour is paid for, leaving a net return of £50 per acre.

The progress of the industry will necessarily be slow for some years to come, and when a few growers have demonstrated the profits to be made, greater strides will be made in the development of the industry.

Meantime, further improvement can be made in the heavy types by better systems of curing and cultivation, and the use of improved varieties; but such types can be easily over-produced, and the bright aromatic tobaccoes should be made the chief objective.

In any general consideration of the Australian tobacco industry it is impossible to ignore the fact that the grower is practically dependent on a single combine for the sale of his leaf. When it is found that this combine is largely controlled by British and American companies, and that its shares are almost entirely in the hands of persons outside Australia, it is natural to wonder whether, if the monopoly were in the hands of the Government instead of in the hands of a foreign combine, the local growing of tobacco might not receive greater encouragement. The idea of a Government monopoly is one which is probably opposed to the ideas of most of us, but, nevertheless, it deserves careful consideration.

The following figures are suggestive :—

Year.	Country.	Revenue per Head.
		s d.
	Revenues from Specific Taxes on Tobacco per Head.	
1912	New Zealand	11 5
1912	Australia	8 7
1912–13	United Kingdom	7 4·5
1912–13	Canada	5 10·5
1912–13	United States	4 4
1912	Germany	2 7·1
	Revenues from State Tobacco Monopolies per Head.	
1912	France	8 5
1913	Spain	6 2·2
1912	Austria	5 9·7
1912–13	Italy	5 8·1
1912–13	Japan	2 2·1

We may also consider the position in Sweden, since the population of that country is about the same as that of Australia, being 5,541,000. The average revenue from the tobacco monopoly during the years 1909–12 was £337,780, or 1s. 2½d. per head; but new revenue taxes were expected to produce 3s. 1d. per head in 1916 and 4s. per head in 1917. The spending capacity of a people has a great influence in this connexion. Australians are said to smoke a better-quality tobacco, on the average, than the people of any other nation.

The following table shows the consumption per head in various countries and the net revenue per lb. :—

Country.	Average Revenue from Specific Taxes.	Consumption.
	s. d.	lbs.
New Zealand	4 4·6 per lb. sold	2·75
United Kingdom	3 3·4 per lb. consumed	2·25
Australia..	2 10·5 „ „	3·00
Canada	1 6·6 „ „	3·81
United States	0 9·1 „ „	5·71
Germany..	0 8·2 „ „	3·76

Country.	Average Revenue from State Monopoly.	Consumption.
	s. d.	lbs.
Italy	4 4·6 per lb. sold	1·22
France	3 5·7 „ „	2·41
Spain	2 11·9 „ „	2·06
Austria	1 10·9 „ „	2·95
Japan	1 6·5 „ „	1·41

Tobacco is regarded as a fit object for taxation in all countries. Monopolies in tobacco exist in France, Italy, Austria, Hungary, Japan, Roumania, and Serbia ; whilst in Spain, Turkey, Portugal, and Sweden monopolies are leased to concession companies. In France the President by administrative decree determines the prices at which various kinds of tobacco are to be sold, general alterations in prices for taxation are referred to Parliament, whilst the monopoly acts on its own initiative in raising prices when the higher cost of production demands this. There are 21 State factories of all kinds of tobacco under a central administration.

The staff is divided into three categories :—

(1) Permanent civil servants, comprising agents and computers employed in supervising plantations, managers of warehouses and factories, and engineers and officials in factories.

(2) Foremen, forewomen, and overseers of workpeople.

(3) Men and women labourers chiefly employed on piece-work.

Women workers predominate in the ratio of 6 to 1. Workers contribute 1 per cent. of their wages to an old-age pension fund, whilst the administration pays to that and other philanthropic services a sum equivalent to 16 per cent. of its expenditure on wages paid direct to employees.

The retail business for the sale of tobacco is let in each area to the highest bidder, or ceded by patronage to deserving persons or State *protégés*. Frequent inspection is made by officials.

The revenue from the monopoly was stated to be £17,421,300 in 1912, but no debit for rent of land and services by other State Departments appears to have been charged.

In 1904–5–6 an Australian Royal Commission of five members inquired into the question of the nationalization of the tobacco industry, and reported in favour of this course. They estimated an increased annual revenue due to nationalization of £402,572, but since that date the consumption of tobacco in Australia has greatly increased.

Discussion of Mr. Smith's Paper.

Prof. Watt said there could be no doubt that Australia was too dependent on a single crop, and it would be better if agriculture were more diversified. There was no doubt that practically every class of tobacco could be grown here if some of the difficulties could be got rid of. One of the greatest difficulties was the marketing of the crop. If the crop could be marketed in the leaf as cut, the farmer would soon learn the business and make it a success, but he could hardly be expected to put up an expensive curing plant and undertake this process for himself, especially when the price was so problematical. The curing of the leaf was a matter for skilled people or for co-operative effort under skilled direction, and flue-curing was absolutely essential for the production of the class of leaf required in Australia. The whole industry depends upon finding a market, and he would like to have Mr. Smith's ideas as to the most practical way in which to set about assisting the industry.

Mr. Pye thought there were two main aspects of the question. One was legislation. There seemed little doubt that the monopoly secured by the tobacco combine was harmful to the industry, and legislative action might do something to help in this direction. The other aspect was that of education. Most growers did not know much about curing, and the fact that the extra prices paid for cured leaf were not commensurate with the extra trouble and cost involved did not encourage them to cure the leaf properly. He recommended that travelling scholarships should be provided, so that agriculturists might study the methods adopted in other countries.

Prof. Perkins said that most of us were averse to a Government monopoly, especially if we had smoked the tobacco of countries where a monopoly was in existence. He supposed, however, that there was no real reason why high-class tobacco should not be produced under a Government monopoly.

He instanced two countries where private monopolies had killed the local tobacco industry, viz., Tunis and Egypt, in neither of which tobacco was now grown. It was easier for the monopoly to keep control if all the tobacco was imported, hence it tended to suppress local production.

Mr. Smith, in replying, said that he had given much careful consideration to possible methods of encouraging the industry. The system of giving bounties to the growers of better-class leaf had been tried, but it did not work in Victoria, since the buyers reduced the prices and thus got the benefit. Another possibility was for the Government to fix standard prices to be paid for standard qualities of leaf, but he did not think this would succeed. The whole question reduced itself to the rival advantages of a private monopoly or a Government one, and he was convinced that a private monopoly was bad for the industry. A large number of shares in the Australian companies were held by companies in other countries. Many of these companies consisted largely of American warehousemen, who bought up the leaf and sold it to Australia. He had therefore come to the conclusion that a Government monopoly was the only solution.

If a Government monopoly were declared, he thought that a large number of young men, many of whom might well be returned soldiers, should be trained in tobacco-curing, and should then go round and teach the growers how to deal with their crops. There were many thousands of acres in Gippsland which could produce a higher class of tobacco than the districts where it was being grown. The tobacco plant is not an exhaustive one to the soil, being a small feeder on phosphoric acid, a fairly large nitrogen feeder, and a heavy potash feeder. By using sulphate of potash the grain of tobacco and its combustion could both be improved.

For a long time the price paid was 6d. per lb., and years ago this was a fair price, but a leaf that was grown for 6d. ten years ago could not now be grown for less than 1s., owing to increases in cost of labour, transport, &c. The buyers had not raised the prices in proportion to the increased cost of production, with the result that the tobacco industry was perishing.

NATIVE GRASSES AND FODDER PLANTS OF AUSTRALIA.

By E. Breakwell, B.A., B.Sc., Agrostologist, Department of Agriculture, New South Wales.

The importance of the native grasses and fodder plants of Australia is gauged by the fact that considerably more than half the wealth of the Commonwealth is derived from the pastoral and dairying industries. Four questions then naturally arise :—

(1) Will these industries always be absolutely dependent on our native pastures ?
(2) If so, will the native grasses and fodder plants, if treated and managed as they have been in the past, always be as productive as they are now ?
(3) Are there any practicable means by which the native pastures can be maintained or improved ? and
(4) Is the problem one of pure investigational research, or direct practical method, or both ?

In considering the first question, viz., Will the dairying and pastoral industries be always absolutely dependent on our native pastures ?, the answer is yes, unless there can be substituted some other grasses and fodder plants with the same or greater productive capacity than those that exist at present. Now, in considering the possible substitution of other grasses and fodder plants for our native pastures, we would do well to treat Australia as having three climatic zones, viz., the coastal zone, with the ordinary temperature and decent rainfall of temperate zones ; the zone of the tablelands and slopes, with a temperature more one of extremes and only a moderate rainfall ; and the interior, with high summer temperatures and a low rainfall.

It has been practically shown that in the coastal districts the substitution of introduced grasses and other fodder plants for native grasses is a practicable and paying proposition. One has only to consider the continual increase in the manufacture of ensilage from maize and sorghums, and the laying down of artificial pastures, such as cocksfoot, rye, Paspalum, and Phalaris for New South Wales and Victoria, Para, Guinea, and Rhodes grass for Queensland, to realize the significance of this. Exclusive of these cultivated pastures, there are certain native grasses to which there is a considerable amount of importance attached, viz., Couch, the Love grasses (*Eragrostis*), the Danthonias, Deyeuxias, Dichelachnes, Cenchrus, &c. It is far easier, however, as will be shown later, to guarantee a cultivated pasture using introduced grasses than by using native grasses, and the area under such introduced grasses is continually increasing. We can therefore dismiss the idea of the indispensability of native grasses for coastal districts. The climatic conditions, including temperature and rainfall, are similar to those of countries whence many cultivated grasses can be obtained, hence their success.

In considering the tablelands and slopes, however, the problem becomes considerably changed. In the New England district and extreme southern tableland districts of New South Wales, where the winters are long, and where the short, hot summer is compensated for by a liberal rainfall, introduced grasses such as cocksfoot, rye-grass, Timothy, and Phalaris, are grown successfully. In the other portions of the tablelands and slopes, however, the central highlands of New South Wales, those of Victoria, South Australia, and Western Australia, although the mean average temperature is fairly low, the summer temperatures can reach very high proportions, and, unlike the New England district, are not compensated for by a good rainfall. The result is that introduced grasses like cocksfoot, rye-grass, and others, accustomed to an average temperature and a decent rainfall, are often killed out the first summer, when one attempts to grow them. It is only introduced grasses capable of enduring dry spells and high temperatures that can be substituted. These are very few and far between, and at present it is only such grasses as Sudan and Rhodes that are showing any hopes of success. The question of growing sorghums, maize, rape, and other fodder plants for mixed farming areas which are confined mostly to the tablelands and slopes here arises, but it will, perhaps, be more convenient to deal with this matter later. At present we can definitely state that native grasses are practically indispensable in the tablelands and slopes as far as the pastures are concerned.

In the interior the climatic conditions become even more acute for the introduced grasses, and at the present time it is only an occasional pastoralist who is foolish enough to attempt the laying down of an artificial pasture, except, perhaps, it be Rhodes or Sudan grass. It is impossible to get blood out of a stone ; in other words, it is impossible to expect a structure in a plant capable of enduring arduous conditions when it has been bred and grown in a country with satisfactory climatic conditions.

There is no doubt whatever that the native grasses can retain their vitality remarkably well under phenomenally dry weather conditions, and it appears that the whole structure of the grass is adapted to this end.

In two publications in the Proceedings of the Linnean Society of New South Wales, I have shown how the leaves of many of our native grasses are admirably adapted to endure dry weather conditions. The root system of many also, such as that of *Eragrostis falcata*, *E. eriopoda*, many of the Panicums, and others, is often invested with a woolly covering, which may be said to act as a blanket or protecting sheath, preventing evaporation and the drying up from hot winds. Also in many cases and for the same purpose sheaths of dead leaves are seen at the base of the stems. The tussocky habit of many of our native grasses is also an aid in preventing destruction by drought conditions, as the central portion of the plant is shaded and protected by the outer. It is almost impossible to conceive of all or any of these structures acquired by introduced grasses, and thus the latter cannot survive under semi-arid or arid conditions. We can therefore definitely state that the pastoral industry is at present, and is likely to be, absolutely dependent on our native grasses and fodder plants.

2. We now arrive at the second question—Will the native pastures and fodder plants, if stocked and managed as in the past, be always as productive as they have been or are now ? One might easily ascertain the productive capacity of our pastoral areas, if the number of sheep noted in the statistical *Year-Book* from year to year was the exact number our pastures could carry. Droughts and other mishaps, however, deplete our flocks so severely that, for many years, even an average stocking cannot be maintained, until, with a run of good seasons, the extreme number is again arrived at, and, in some cases, overstocking again indulged in.

But, from a yearly periodical examination of the composition of our native flora, there is no doubt that deterioration of our native pastures is taking place, and, in some cases, more rapidly than in others. The causes of such deterioration may be attributed—

(1) To the introduction of weeds and other aliens.

(2) To depredations from rabbits.

(3) To the effects of droughts combined with overstocking.

1. *Introduction of Weeds and other Aliens.*—The tablelands and slopes, during the spring months of the year, present a brilliant appearance. To the ordinary observer the verdant green and magnificent growth mean a high appreciation of our pastures. But, on closer examination, it is found that this magnificent growth is not from native grasses or fodder plants, but almost entirely from introduced aliens, such as burr-trefoils, barley grass, introduced crowfoots, rat's-tail, fescue grass, &c. In their young stages these plants provide fine feed, but, being wholly dependent on cool temperatures, light evaporation, and abundant moisture, their life is short. As soon as the drying hot winds of summer approach they are no more, and all that is left is a brown mass of innutritious leaves, with an abundant supply of seed and burrs on the earth. But this is not all. By their aggressive habits and dense growth they have crowded out the native grasses and fodder plants, which, in the ordinary course of events, commence to show themselves in the spring. The spring rains germinate any native grass seed which may be in the soil, but the struggling seedlings fail to reach the light amongst such an abundant mass of herbage, and the opportunity for producing feed in the summer and autumn months is thus lost. The area of such herbage country in New South Wales alone is very considerable, but is thickest on the higher tablelands and slopes. Were cultivated pastures or fodder crops grown during the summer months to compensate for the loss of native grasses all might be well. Stock, however, in most wheat areas has to subsist on stubble, fallowed land herbage, and weeds, or on hay. The autumn months are practically critical, for then the stubble has lost its value, and the herbage growth on fallowed lands has practically disappeared. A native pasture at this season of the year is particularly acceptable.

Even in the plain country, such as the Western Riverina and the black soils of Coonamble and Moree, the introduction of foreign herbage and alien weeds is assuming startling proportions, and what must have been at one time native pasture country is now commonly spoken of as herbage country, which becomes very bare on the approach of hot weather.

Several characteristic and useful grasses are likely to suffer from the introduction of weeds. If we consider the dominant grasses in those districts where the introduced herbage has gained a foothold, we find that the Danthonia and Chloris grasses in the Southern and Western tablelands and slopes germinate their seed in the months of September and October, when the herbage has attained its optimum growth. These grasses are therefore severely handicapped in the struggle for existence, and many of them fail to reach the light. A similar remark applies to the Andropogon and Panic grasses on the North-western slopes, all excellent sheep and cattle grasses for the summer and autumn months.

The problem, therefore, of providing native pastures, either cultivated or otherwise, in herbage country is an important one.

Rabbits.—The damage through this source is well known, and hardly requires comment in this paper.

Droughts and Overstocking.—On well-managed pastures droughts are only a temporary, and not a permanent, evil. Native grass seed has been proved to possess vitality extending over a considerable period. In germination tests with native grass seed, such as *Danthonia semiannularis*, *Panicum decompositum*, and *Andropogon erianthoides*, ten years old, results as high as 50 per cent. were obtained. Information from various sources is available which shows that after a drought extending over a considerable period grasses not observed there previously spring up on all sides, evidently from seed which has lain dormant in the soil. Grass seeds sown in experiment plots at Wagga Experiment Farm which failed to germinate during the big drought of 1914 germinated thickly in 1917, and that after the land had been ploughed and cultivated several times. But on badly-managed pastures there is little seed in the ground to germinate, and once the root system is destroyed the ground remains bare even when the rains arrive. In such country, therefore, the effects of drought are considerable.

In most cases an impoverished pasture is due to *overstocking*. When is land overstocked ? If the grasses are not allowed to seed once a year, or if any spot or spots are allowed to be completely depastured, and the grasses to be replaced by thistles or other weedy herbage, the land is certainly being overstocked, and one soon sees the consequences. The good grasses become less and less in number, and as they are replaced by weeds, the stock leave the latter and eat out the few good grasses that remain. The natural consequence is either the existence of bare patches, or the substitution of weeds and noxious grasses for good pasture plants. Once such deterioration commences it increases, not in the same constant proportion, but in a proportion multiplied year by year. Miles of country in New South Wales are now covered with thistles and other useless herbage, country that once had a profitable carrying capacity. A grazier naturally desires to produce from his land the largest amount of wealth he can by stocking to the fullest capacity, but the maximum financial results cannot be maintained by doing so. We are justified in assuming that an overstocked selection which carries one sheep to an acre will in fifteen years carry only one sheep to 3 acres. If, then, on a station, say, of 3,000 acres the maximum stocking is one sheep to an acre, and the optimum (or desirable) stocking one sheep to 1½ acres, in fifteen years 45,000 sheep will have been carried by maximum stocking and 30,000 by optimum stocking. But by this time the carrying capacity of the overstocked land will be 1,000 sheep for 3,000 acres, while that of the optimum stocked land will be 2,000 sheep for the same area. Extending this period over another 30 years, 30,000 sheep will have been carried on the maximum stocked land, and 60,000 on the optimum stocked land. So over a period of 45 years £15,000 more (valuing the sheep at £1 per head) will have been produced on optimum stocked land than on maximum stocked land. In this hypothetical case we assume that the land suddenly deteriorates after fifteen years from one sheep per acre to one sheep per 3 acres ; whereas deterioration commences right from the beginning, and the profit from optimum stocking would be greater still. Again, the area considered is a comparatively small one. When we consider the millions of acres in the Commonwealth that are likely to be thus overstocked, not only do we realize the damage done to our native grasses, but also the financial loss to the State and Commonwealth. The trouble is that the lessee of a country is not concerned with the future carrying capacity of his land. He lives for the present, and gets as much out of it as he can for the present. But it is an argument that should appeal to the permanent owner, the State, and the Commonwealth, all of whom are concerned with the condition of our pastures for future generations. Something must certainly be done unless we wish to be confronted with the same difficulties with which America was faced, viz., depletion of pastures and the consequent great financial loss and expense of renovation.

This leads us to the third question, viz., Is there any practical method by which native grasses can be maintained or improved. At this stage it will be profitable to review the work carried out in the past by the Department of Agriculture in New South Wales. About seven or eight years ago grass gardens were established at the coastal farms and at some of the farms in the interior. In the case of the coast mostly introduced grasses (but some native) were sown, while in the interior native grasses were planted from roots. Although the plots were small, averaging a few square yards, this work was particularly valuable, inasmuch as it brought exactly before one's eyes the behaviour of our native and introduced grasses, thus enabling us to study their permanence, their rapidity of growth, and their drought-resisting qualities. It was found that, as far as the interior was concerned, the native grasses were superior to nearly all the introduced grasses in practically every respect, but mainly as regards permanence. After a period of seven or eight years introduced grasses like rye-grass, cocksfoot, Timothy, tall fescue, and others have disappeared, and now only a few introduced grasses like Rhodes, Sudan, *Phalaris bulbosa*, and *Bouteloua* sp. (Grama grass) appear to hold their own with the native grasses.

At the same time our native grasses showed characteristics which would limit their usefulness. Desirable qualities were looked for, such as quickness of growth, aggressiveness, free-seeding habits, and palatability. Two problems then presented themselves—

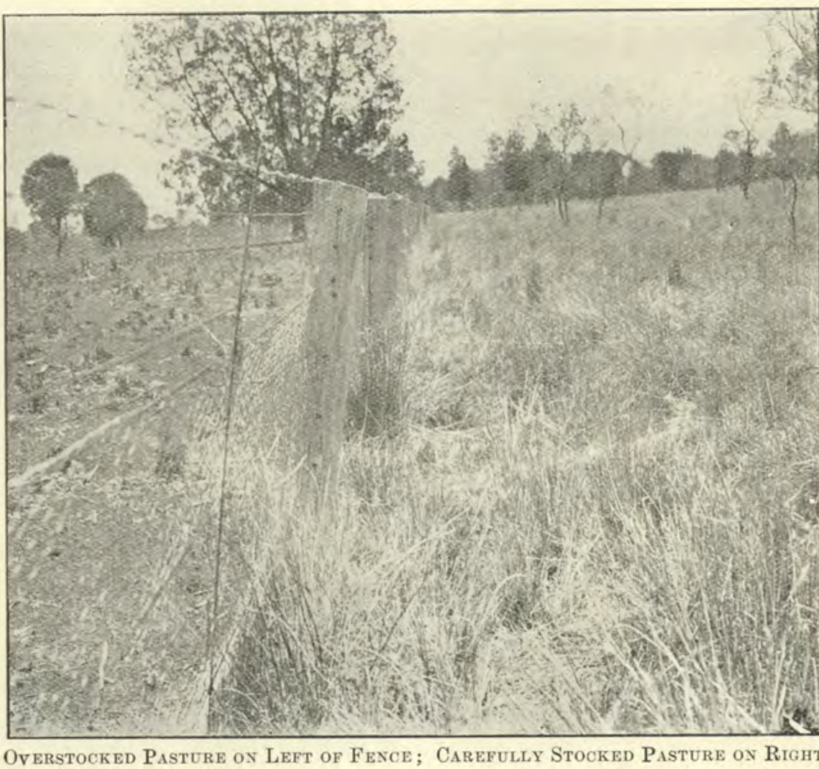
1. In what way could the native grasses be rendered most useful in areas where closer settlement prevailed, and where cultivation was practicable, and in what way could they be utilized in the best possible manner where cultivation is not likely, such as in the big pastoral areas of the interior? It was felt that if cultivated pastures of native grasses could be obtained on the tablelands and slopes a considerable benefit would be bestowed on the community, but that these pastures must be obtained by sowing seed and not by planting roots. I then attempted to establish good-sized plots by sowing the seed of some of our best native grasses, about 20 or 30 in all. Many failures had to be recorded, mainly through the bad germination of the seed. Whereas a stand from sowing seed of such grasses as rye grass or cocksfoot can be assured, this is not so with native grasses; and I have found that a considerable amount of investigation is necessary before a permanent pasture can be secured. This led to a study of the characteristics concerning the seed, such as viability, the optimum temperature for germination, the improvement of seed by selection and grading, and the optimum depth of covering the seed. I have been fortunate as regards these experiments in possessing a germination chamber in which the temperatures can be

regulated. There appears not the slightest doubt that not only is there an optimum temperature for the germination of our native grass seed, *e.g.*, *Andropogon erianthoides*, 80° ; Mitchell grass, 85° ; Danthonia, 65°–70° ; *Panicum decompositum*, 75° ; *Panicum prolutum*, 75° ; but there is also an optimum time of the year for this germination. Whereas in many introduced grasses the seed can be made to germinate at any time of the year given the right temperature, this is not so with our native grasses. Such investigations, as outlined above, have now extended over a considerable period, and have been correlated with experiments in the field as regards palatability, quickness of growth, drought resistance, and good seeding characteristics, easy to handle, &c. In addition, the quickness of germination and the maximum temperature limit at which the seed will germinate is studied. As a result, it is quite probable that Coolah grass (*Panicum prolutum*), Warrego summer grass (*Panicum flavidum*), Australian millet (*Panicum decompositum*) and satin top grass (*Andropogon erianthoides*) will become promising grasses for cultivated pastures ; while no definite decision has yet been arrived at concerning Mitchell grass and Queensland blue grass. Here I am faced with a considerable difficulty. From results it has been found that a better germination exists in the seed of Mitchell and other grasses sent from Queensland than that from New South Wales. For this work to be carried out thoroughly the best strains of grasses and other fodder plants should be chosen, and these strains are not confined to one State alone. Queensland possesses Mitchell and Flinders grasses far surpassing those of New South Wales, while very likely promising strains in the Northern Territory are practically unexplored. If this is to become a national or even State undertaking, carried out efficiently, then opportunities should be provided for extending one's selection work to all States. The United States of America have agricultural experts travelling all over the world in search of new grasses and fodder plants, and already a vast amount of financial benefit has resulted from such investigations. As far as our native grasses and fodder plants are concerned, there is not one individual State which possesses any special monopoly, and much more satisfactory results could be achieved if a selection for the foundation could be made from all the States. To come back to the work carried out at the experiment farms, grass gardens are still being maintained. In these gardens various grasses, both native and introduced, are continually being tried. The most successful are then transferred to small plots. Selective methods on these areas are studied. Seed from the best plants is harvested, and the areas gradually increased to ¼-acre or ½-acre plots, and they then may be termed seed reserve areas. Experiments in grading, germination, &c., are carried out, and just lately the laying down of cultivated pastures with such seed for feeding-off experiments has commenced. At the same time the total yields of green feed per acre from different native grasses are being determined.

Problem on Pastoral Areas.—It is quite possible that in the course of time pastoralists will have recourse to cultivation in order to produce a greater quantity of feed. This is already seen in out-back localities, where lucerne growing has been found to be practicable. I have also found that Sudan grass is sown by pastoralists in districts where it will grow satisfactorily. If the pastoralist were given a guarantee that the success of a good grass or fodder plant could be assured by cultivation, he would probably, given decent labour conditions, attempt such cultivation. For the present, however, it appears that more might be done as regards the maintenance and improvement of native pastures on big pastoral areas by methods other than by cultivation. An experiment is being carried out at the present time at Coonamble Experiment Farm (typical of the black soils) in which three paddocks are being treated differently. One paddock is being overstocked, one is protected from stock, and one is only stocked at certain periods of the year, viz., when the grasses have ripened their seed. A number of square units have been pegged out in each paddock. The flora in these units is investigated from time to time, and the composition, percentage, &c., noted on graph cards corresponding in size to the units. It will thus be possible at the end of a certain period, say four years, to state definitely the damage done to the overstocked paddock, and the improvement that has taken place in the other two. At the same time experiments are being conducted to determine any improvement or deterioration that might take place in the viability of the seed in each paddock. Also seed of good native grasses is scattered in certain patches in the protected paddocks to ascertain what increase in stand will take place.

There is very distinct evidence in New South Wales of the beneficial results arising from the careful management of pastures and avoidance of overstocking. The accompanying photograph (Plate VI.) depicts the difference between an overstocked and a carefully stocked pasture. On the former

PLATE VI.



OVERSTOCKED PASTURE ON LEFT OF FENCE; CAREFULLY STOCKED PASTURE ON RIGHT.

were either thistles or bareness, while on the latter some of the best grasses, including Mitchell grass, Brown Top, and good Panic grasses were both abundant and luxurious. The latter result was due, according to the testimony of the manager, to the fact that grasses in alternate paddocks were allowed to ripen their seed. This same pastoralist also studied the habits and characteristics of every grass on his estate. The good grasses were carefully watched and protected, seed was scattered in bare patches in order to increase the stand of such grasses, and the latter protected until they had reached maturity. This experience is quite different from that of the ordinary pastoralist, who hardly knows the habits or even the names of the grasses on his estate. To very many introduced annual grasses, herbage, and even weeds are simply "grass," and no differentiation whatever is made between the various plants. Surely the pastoralist can be impressed in some way with the importance of this national problem, but there appears no doubt that the State must lead the way. Much might be done by the establishment of native grasses at our Public Schools, whereby the pastoralist's son learns first hand the characteristics of our native grasses. A commencement has been made in this direction in New South Wales, where the work is carried out at three or four schools.

America was forced, through the eating out of good grasses on range lands, to investigate the problem of pasture management. An experiment on lines somewhat modified from that at present being carried out at Coonamble Experiment Farm previously described was conducted. It was undeniably proved that if alternate portions of the pastures could be so protected as to allow for the maturity of the seed of the grasses, the maximum results could be achieved. By a method of continued protection a great amount of feed is lost, whereas under a system of deferred grazing the ripened grass was secured as feed. This point is particularly valuable as far as New South Wales is concerned, for there is no doubt that a great amount of nutriment and vitality remains in the grasses right up to the end of the season. This is an experiment that can well be carried out in other areas such as the red soil area of the interior and the Riverina country, and it is hoped that when conditions are more stable an opportunity will be provided for doing this.

In reference to the work carried out with the cultivation of grasses and fodder plants at the various experiment farms I have been somewhat handicapped by the lack of trained assistance at such farms. In spite of this fact, however, the work has now been carried on through the three stages, viz., the trials of grasses and fodder plants in grass gardens, the establishment of selection and seed reserve areas of the most promising, and the laying down of areas large enough for stocking and feeding off. The farms at which the work is carried out are Bathurst, 10 acres; Hawkesbury Agricultural College, 10 acres; Berry, 4 acres; Cowra, 12 acres; Wagga, 12 acres; Glen Innes, 10 acres; Yanco, 10 acres; Grafton, 2 acres; Wollongbar, 2 acres; and Nyngan, 12 acres. Farmers' experiment plots with native grasses were also established this season.

Work with Native Fodder Plants.—Very little has been done with problems concerned with native fodder plants other than grasses. This is due to the fact that no assistance is forthcoming to carry out the essential propagation work. The Forestry Department of New South Wales has taken a lead in propagating Kurrajong, Old Man Salt Bush, *Rhagodia hastata*, Belah (native), and Tree Lucerne (introduced). These have been raised on the coast and distributed in the interior. Although this work is not yet far advanced, there is already good evidence that this method of propagation on the coast and then transferring to the interior is not a wise one, as lack of acclimatization soon affects the seedlings, and many of them have already died. I have also noticed this in propagating native grasses at the Botanic Gardens in Sydney and thence transferring them to the interior. They become seriously affected, whereas seedlings propagated in the interior are particularly hardy. Owing to the clearing of scrub country for grass, bush fires, droughts, and overstocking our stock of native fodder plants like Salt Bush, Wilga, Kurrajong, Mulga, White Wood, and Belah is becoming seriously depleted.

An excellent method of maintaining a supply of these fodder plants is by the establishment of cultivation reserves. I believe that many pastoralists would in time establish such reserves if they could be supplied with the trees at small cost from the State Nurseries in the interior.

In reviewing the preceding pages, it is clear that the problem of our native grasses and fodder plants is both a practical and investigational one. The aim is to bring the importance of the grasses and fodder plants directly before the pastoralist. Nothing can do this better than field work. Cultivated pastures must be successfully established and economically stocked before the wheat and sheep farmer can be induced to do likewise. The large landowner must see direct and practical results from a systematic management of a pasture before he will do the same. At the same time, to obtain the full and complete knowledge of the grasses investigational work must be carried out. Selection work, seed investigations, palatability tests, chemical analysis, combined with the analysis of excreta from animals feeding on certain grasses, should be undertaken, together with feeding-off experiments to determine the carrying capacity of certain definite grasses.

To achieve this in a completely satisfactory manner specially trained assistance is necessary. This assistance is specially required for those Experiment Farms in the interior where the native grass work is particularly valuable. The foundation of such work has already been laid at suitable farms in the interior, viz., Wagga, Cowra, and Nyngan. One would like to see a special station established at Nyngan, where propagation work, palatability tests, water requirements of plants, and other essential work could be carried out. Work can be carried out at this farm which would be useful and practicable to the semi-arid districts of the interior, which embrace a considerable area. It is also necessary, however, to carry the native grass work out at Cowra and Wagga to suit these respective districts. As before pointed out, the work of selection and improving the quality of seed by such selection plays a very important part in the native grass problem. Now, hitherto, the seed from such selected plants has to be sown at the Botanic Gardens, and the plants thence transferred to the farms. But the plants are too tender and succulent owing to being thus raised, and become seriously affected when transplanted. If specially trained assistance could be given at the farms in question propagation work could be carried out on the spot. Reference has been made to the superiority of many native grasses in Queensland over those of New South Wales. Emphasis might be placed on the different species of Mitchell, Bull, Curly and Hoop Mitchell, Flinders grass, and many Panic grasses. To secure the best strains of these grasses personal or skilled investigation is really necessary. There is little doubt that the Queensland Agricultural Department would heartily co-operate as far as the Queensland grasses are concerned, and similarly with the other States. Much might be done with the Salt Bushes of Western and South Australia.

At the same time we should not lose sight of the fact that it may be possible to introduce a stray grass or fodder plant equal to our own. This has happened in the case of Sudan grass, and the intended Federal body which will eventually take charge of seed importations will be in an excellent position to choose those foreign fodder plants whose climatic requirements are somewhat similar to our own.

I must admit that all my knowledge of the capabilities of native grasses in Western Australia and South Australia is based on written statements, and I am unprepared to guarantee that the grasses experimented on in New South Wales will succeed in those States. The problem is one for special investigation, and until such can be given we can only further this work by distributing seed of grasses grown in the different States which the respective State experts may consider worthy of trial in their States.

Such is the problem of our native grasses and fodder plants. The public interest in this matter is continually increasing in New South Wales, as shown by the fact that between six and seven hundred packets of seeds were distributed to applicants last year, in addition to very numerous requests for advice *re* pastures, &c. The number of farmers' experiment plots is also constantly increasing. The work, however, is only in its infancy. It should be a national one, and to be carried out efficiently and practically must be backed up by financial as well as sympathetic encouragement extending over a considerable number of years.

Discussion of Mr. Breakwell's Paper.

Mr. Pye stated that 25 to 30 years ago there were a number of fine grasses in the Dookie district, including species of Andropogon, Panicum, and Danthonia, but they had almost all disappeared, owing either to rabbits or to sheep. Among the Andropogons there were many varieties varying in value, and he had noticed that the stock favoured different varieties at different seasons. If something was not done, we should lose many of our grasses altogether. He thought that each farmer should have a small area enclosed with wire-netting, so that seed should be produced for re-sowing depleted areas.

He congratulated the New South Wales Government on having appointed Mr. Breakwell to undertake work of this nature, which was urgently required.

Mr. Quodling expressed his appreciation of the many valuable suggestions that had been put forward by Mr. Breakwell. In Queensland, the grassing of coastal land was going on apace, Paspalum and Rhodes Grass being utilized. This work should insure the continuity of the supply of fat stock to the local markets. In regard to Para Grass it had been found that it would only seed in the northern part of the State, and he would be glad of advice as to the best method of propagating it commercially. Sudan Grass had proved excellent, and had borne out the reputation it had obtained elsewhere.

Attempts were being made by the Queensland Agricultural Department to arrive at the carrying capacity of the native pastures. The plants were identified and analyzed chemically. He thought such work should be carried out on a larger scale. Crosses had been made between Rhodes Grass and a native grass, and some of the hybrids showed the habit of the native grass, while others had the running habit characteristic of the Rhodes Grass. He thought this work might prove valuable. He also suggested that reserves should be established where edible trees and shrubs could be preserved and propagated.

Mr. Sutton said that the success of wheat-growing in some parts of Western Australia was largely dependent on having suitable grasses and fodder-plants to carry the stock through the winter months. One obstacle was the difficulty experienced in obtaining the seed of native grasses, as the seedsmen paid no attention to them, and he thought this was one of the reasons why pastoralists were not so enthusiastic as they might otherwise be. Mr. Breakwell was doing most important national work, and he hoped he would be able to select valuable types and breed them in pure lines, so as to establish them over wide areas.

Prof. Perkins referred to the experience of South Australia with regard to Paspalum This grass had been introduced because it was said to be drought-resistant, but drought-resistance was a relative term, and Paspalum would not stand the South Australian summer without irrigation. On the irrigation areas it established itself so firmly as to become a pest, and took the place of other more valuable plants which could be grown under irrigation.

He thought that unless conditions in New South Wales were very different from those in South Australia, it was unlikely that pastoralists would sow grass seed. The pastoral industry had been built up on the basis of no cultivation, and it was doubtful whether any cultivation would be economically possible until the very large areas were subdivided. Most pastoralists maintained that sheep allowed to pick up their own livelihood were hardier than those raised on cultivated areas, and quite recently the Royal Agricultural Society had refused to give prizes to sheep raised on cultivated land. He thought they would regard the sowing of grass seeds as cultivation. However, Mr. Breakwell's work would be of great value when the inevitable subdivision of the large stations took place.

Mr. Breakwell, in replying, said that Para Grass had a creeping stem, any portion of which could be used in propagation. The crossing of grasses was very difficult and uncommon, and he thought that selection was the best means to adopt in improving the varieties. The absence of a supply of seed was a real difficulty, but he was hoping eventually to grow sufficiently large areas of valuable grasses to supply the demand Good pastoralists with whom he had come in contact, took a great interest in increasing the valuable grasses on their estates ; one he knew always carried seed on wet days and sowed it in bare patches. The interest in grasses and grass improvement was steadily increasing.

FIFTH SESSION, 15th NOVEMBER, 1917.

THE POSSIBILITY OF CULTIVATING FIBRE PLANTS IN AUSTRALIA.

By T. Hogg.

As a business man, I need scarcely say I am not in the habit of delivering lectures, but I will do my best to interest you in the possibilities of growing fibre in Australia. May I first be allowed to say a congratulatory word as to the great importance of your Conference. The eyes of Australia are upon you, and I do sincerely hope, with the people of Australia generally, that you will be able to widen our agricultural activities, so that Australia will be more and more self-reliant.

My object is to deal with the question of fibres, and the possibility of their being grown and produced profitably in Australia. Fibres are divided into two main classes—hard and soft fibre. Hard fibres are products of the perennials, soft fibres of the annuals. Commercial fibres are not very numerous, so that I think we can, perhaps, better understand our subject if I put before you samples of the different fibres that are common in commerce, state where they are produced, and indicate whether it is at all likely they can be produced in Australia.

I will start with the hard fibres, and will take first the leading hard fibre—Manila hemp, derived from *Musa textilis*, which is a product of the Philippine Islands. It is a magnificent fibre, of wonderful length and great strength, used for the manufacture of the better classes of rope and cordage. Outside the Philippine Islands you cannot find good Manila hemp. The fibre from the Borneo plantations has always been unsatisfactory. In the Philippine Islands there is something in the rainfall and soil which makes for the successful production of Manila hemp. A good season's crop will be 1,000,000 bales, 8 bales going to the regular ton. Although a very beautiful and important fibre in the world's commerce, we need not further consider it this morning.

Next to Manila hemp is Sisal hemp; samples of this fibre, which have reached us from Papua, are of excellent quality. This Sisal has a future, and is worthy of the notice of those of you specially interested in tropical productions. You ought to encourage the growth of this fibre as much as you possibly can.

Mauritius hemp is also the product of an Aloe (*Furcræa gigantea*) grown in Mauritius, and Aloe fibre is produced practically wherever Aloes will grow. The Sisal is the most valuable of all the products of that order, and we desire, as Australian manufacturers, that our requirements of fibre for twine and rope and cordage should be more largely satisfied in the future by the production of Sisal hemp in Papua, and even in Queensland. In the latter there is a certain limited production at the present time, but the difficulty is the question of labour. Wherever you go, where fibres are produced, I am bound to admit, cheap labour abounds. In the Philippine Islands you have cheap labour; in Java, cheap labour. In German East Africa the Germans thought so highly of the importance of encouraging the growth of Sisal that they put hemp on one side, using Sisal for their navy in preference to using the superior quality, high-grade Manila hemp. We ought to produce thousands of tons of this a year; we ought to encourage the planters of Queensland and Papua to grow it; we ought not to allow the paying rubber plantations to destroy Sisal plantations. We ought to see that they not only grow rubber, which pays so highly, but also Sisal hemp. In Australia alone about 3,000 tons a year of binder twine are required by our farmers, and to a very large extent this could be satisfied by the production of Sisal.

The *Agave sisalana*, from which Sisal is derived, has its home in Yucatan. It is exported from the port of Progreso. The requirements of the United States run into something like 100,000 tons per annum, mostly satisfied by the production in Yucatan, Mexico, and the Bahamas, and therefore I have no hesitation in recommending you to consider to the full the production of Sisal in our tropical parts.

Another very important hard fibre is New Zealand hemp, obtained from *Phormium tenax*. It is also a perennial. Of this the production in New Zealand in a good year would run from 30,000 to 40,000 tons. The industry has been failing somewhat during the last few years because of the difficulty of competing from the labour stand-point. Cheap labour is needed for the production of Sisal; cheap labour for the production of the greatest world fibre—jute. There is cheap labour in Russia and in Italy, and wherever fibre is produced in large quantities you find cheap labour. This is going to be a very serious question for you, and it is right for me to warn you to consider it in connexion with anything you may recommend for the production of fibre in Australia. Superior methods of cultivation, cheaper methods of taking off the crop, and cheaper methods of intelligently dealing with it might compensate for cheap labour to some extent.

We have tried to introduce New Zealand hemp into Australia. Mr. Knight, who was connected with our Agricultural Department, went to New Zealand and brought into Australia New Zealand hemp, and there is a very fair plantation of it growing at Mr. Nobelius' nursery, and we will be only too delighted to help him to strip and turn his leaf into the valuable fibre that is wanted badly by Australian manufacturers. The British Government think so highly of New Zealand hemp that when they wanted to establish an industry at St. Helena they obtained a New Zealand expert to start its cultivation there, and this year they are sending supplies of New Zealand hemp into the Old Country. There is no reason why in Victoria and Tasmania we should not grow *Phormium tenax*. It must have plenty of moisture, with good summer drainage, and from it is produced very excellent fibre, which is the main article used in the manufacture of binder twine in Australia. Of the hard fibres, we might be able to do something in Australia with Sisal and *Phormium tenax*.

Now for soft fibres. Italian hemp is one of the very strongest fibres in the world. A good season's produce would be 80,000 tons. At the present time the price of this fibre is fabulous; before the war I bought this fibre, landed in Melbourne, at £45 per ton. Three weeks ago I paid for the same fibre nearly £230 per ton landed in Melbourne.

There is no difficulty in growing this fibre in Australia. The company to which I belong imported seed in a large way to grow Italian hemp, and for the purpose of establishing the flax industry. We distributed that seed in different parts of Victoria, and I will tell you of our want of success with the flax later on. Italian hemp can be best grown on alluvial river flats, and we chose Orbost. The seed was sent there, and they grew the fibre so well that it killed the industry. The plant will grow to a height of 13 feet, and the male plant will send its shoots as high as 15 and 20 feet. They grew it on the Orbost flats so well that it became an embarassment of riches. In cutting it down there was an awful waste, and, in spite of bad handling, we did get excellent fibre of a mixed character. The farmers, however, would not try to grow Italian hemp again on account of the enormous amount of labour that was associated with their attempts to take off the first crop, largely due to their inexperience. It can be grown. In Italy it forms a most important fibre proposition, and if the Germans are going to press down to the Adige and Po waters past Venice, then it is farewell to the leading soft fibre of the world.

Next we must mention the jute of commerce. This is undoubtedly the fibre that is produced in the largest quantities in the world. It is an annual, and grows to a very considerable height, some 8 feet or 10 feet. There is an enormous production of this fibre. The forecast of the jute crop of 1917 in Bengal, Bihar, and Orissa, and Assam gives an estimated area of 2,729,000 acres, and an estimated yield of 8,964,000 bales. Each bale weighs 400 lbs. net. These figures are almost incredible, showing the magnitude of what has been done in India with the production of this fibre, which owed its introduction into the United Kingdom to the Crimean War. When Russian fibre could not be introduced into the United Kingdom, jute took its place, and has remained there ever since. The enormous requirements for corn sacks, &c., throughout the world will run into the million and a half tons which I have spoken of as the output in India. We could grow jute, but not as a commercial proposition.

India, also, is a land of many hemps. Almost every different province has a fibre of its own. The curious thing is that all the fibres grown in India are very weak and very dusty. This [*showing sample*] is supposed to be a cold fibre that has had all the dross taken out of it in India ; but it is extremely dusty fibre to use in manufacture.

The fibre in which you are most interested is flax. I have asked the growers in Gippsland to send me a small sheaf of this season's crop [*exhibited*]. That will talk better than I can. It tells you at once that in the Drouin district, Gippsland, the flax plant has found a habitation where it can grow to a satisfactory length. This is an excellent sheaf of flax. The growers tell me that there are 460 acres in the Drouin district. Four hundred acres have very good flax; 60 acres are rather poor, because they have allowed the weeds to become dominant in the crop. This is the fibre which is the noblest of them all. It will make the very finest threads that any machine can spin. It is the strongest fibre, and is a fibre of which a large quantity is required. It takes quite a lot of the straw to produce a ton of the fibre. I can tell you nothing fresh about that, and Mr. Richardson would be better able to give you the facts from the growers than I can. My mission is to tell you how to encourage the growth of flax.

Through the length and breadth of Australia not 1 yard of canvas or duck, nor 1 yard of stuff used to make a tarpaulin is produced. There is not in Australia the machinery which will spin this flax. There is not in the whole of Australia a loom to make canvas, and canvas is one of the simplest weaving propositions there is under the face of the sun. So long as the manufacturers depend upon Russia for flax, the flax industry, from the weaving point of view, will be impossible to introduce in Australia. It costs to import flax from Russia as much as six or seven times as much as to import canvas from Dundee. Russian flax is exported from Riga, and before the war there was not one hydraulic press in the place. Time after time we wanted to get our flax sent out to us in pressed bales to cut down freight charges, but this was impossible.

In Japan now they are producing some of the finest canvas that the eye can rest upon. It does not reflect credit upon our enterprise in Australia that at the present time the largest amount of our finest canvas is bought from Japan. Japan has become a manufacturing nation in the last generation and why should Australia lag behind ? Australia should be roused to the serious fact that all the canvas required for our navy, and the duck to cover our soldiers in the field, has got to be imported ; and Australia might be so isolated that she could not import anything, and in time we should be obliged to fall back on something else—what that would be I cannot suggest. We ought to try, therefore, to begin by growing flax. This could be grown in any of our temperate parts. In Egypt it is produced in fair quantities, and there through the winter they get good crops. Flax with us is a winter crop. If sown in the springtime it will run rapidly to seed, but will give poor fibre. I very strongly recommend you to consider seriously how you can encourage the production of flax in Australia. We imported seed, which was tried in Gippsland with great success. It was tried at Alberton, but there was too much labour associated with it to go any further with it. It was tried at Dookie and Tatura, where it ripened very rapidly, and a very short leaf was the result I do not think that it has been fairly tried in irrigation parts yet. There is a good deal of work associated with securing the fibre.

In Russia the crop is pulled, so that in its root end they get a fair amount of fibre, though of very poor quality. We in Victoria and America cut this crop with a reaper and binder. We lose about 3 inches or 4 inches of fibre by doing this, but take our crop off most economically. It is possible to produce a certain quality of fibre and get both seed and fibre, but for the purpose of growing the best fibre, a thoroughly ripened crop should always be produced so that the seed may be passed on at its full strength, and we may not have a deteriorated seed for next year's growth.

After having taken and rippled the seed in Belgium, they sort the flax straw. In that country they have the ideal waters of the River Lys for retting. This river flows very slowly. The flax straw is put into large crates, which are put into the river, and after a few weeks the fibre is retted and becomes free from the straw. The process adopted in Gippsland is to dew-rett. In early experiments bog-retting was carried out there, but you can quite understand that, with a decaying vegetable like that, the waters became most offensive, and when these waters were released and run into the streams it meant great danger to cattle which might drink in lower parts of their courses.

They therefore adopted the system of dew-retting, which produces a darker fibre than bog-retting. The flax-straw is spread out on grass paddocks. The action of the sun, the rain, and the dew set bacteria at work, and they do their part of retting the flax and thus separating the straw from the fibre. After that is done, the straw is passed through a machine called the breaker. This machine is a series of fluted rollers in pairs. The straw is crushed and broken by its action and the fibre made free. The subsequent scutching is a simple mechanical device to beat out the broken straw, and leave the clean fibre in the operator's hands. One character of Victorian flax that we do not like is that it is extremely dry and hard, but at the same time it is a very valuable fibre for our purposes. Being hard and dry might affect it as regards its manufacture into very fine yarns for linen purposes, but, as far as Australian requirements are concerned, this is at present unimportant.

There is only one firm in Australia that can use the production of Australian flax. The needs of the whole world are such that the immediate increase of Australian flax is a necessity.

In Ireland they have increased the acreage by about 12,000 acres this year for flax. If you are to encourage the growth of flax from a national stand-point, certain questions will naturally come up. I am inclined to think that the only way the flax industry can be established is by having small holdings co-operating with a mill, so that the farmer can get the full advantage of his crop. It would be quite wrong to go to a farmer to-day and say that his straw is worth £3 a ton. To-day the resulting fibre is so dear that the farmer should be interested in the result only as fibre, so that instead of getting only £3 or £4 he should, at the present time, get nearly double. If we are to encourage this industry, the farmer should get the fullest possible advantage from the growing of his crop, and not the man who turns the straw into fibre. Of course, if we are to grow flax in a very large way for next year, it will be 1919 before we have any fibre to export. If you communicated with Great Britain, they might give you an order for several thousand tons for 1919. The machinery could be readily produced here, but what I would encourage the Conference to do is to investigate the industry, and see if flax cannot be successfully produced in Australia.

The decline in flax-growing is summed up in one word—labour. The Russian peasants can produce the fibre cheaper than in any other place in the world, therefore they are able to command the world's market for flax, but we may be able to do something, and we should loyally and patriotically try and do what we can, so that if another war came upon the world Australia might not be isolated as now, but could do something more to supply her own wants.

Discussion of Mr. Hogg's Paper.

Prof. Perkins said that it was evident that the main difficulty of growing fibres profitably in Australia was the cost of labour. At the same time, if we could not establish an export trade in competition with other countries, we ought to produce enough for our own requirements.

Mr. Easterby said that experience of Sisal-growing in Queensland had been very disappointing. Hundreds of acres of Sisal hemp were at the present time lying neglected, owing to the difficulty of obtaining labour, and he did not think it would ever be a paying proposition. By means of co-operation something might be done in the way of flax-growing.

Mr. Quodling gave further details of the attempts made to produce Sisal hemp in Queensland. A sugar-grower, who found that some of his sugar lands were showing signs of exhaustion, tried planting Sisal upon them. He imported scutching machinery and produced a couple of tons of fibre, from which the rope and twine makers in Brisbane turned out a very fine article, but the enterprise was soon abandoned, because the land was too rich for the plant.

Subsequently the Lands Department planted 40 acres with Sisal in a mining district rich in lime. It was hoped that settlers would take up further land for the purpose in the district, and thus establish the industry in a compact locality, but this had not occurred, and the man who was working the area planted by the Lands Department could not make both ends meet. If the plant could be grown under a co-operative system, whereby the growers united to employ a high-class machine for treating the fibre in the most economical fashion, it might be a success, but the margin of profit was evidently not large, and it certainly would not pay individuals working independently. There was no question that the plant throve in Queensland, especially on poor soil, provided there was plenty of lime. Up to the present, it has chiefly been grown in the central areas, but it has also been grown on St. Helena Island in Moreton Bay, from which many plants have been sent to Papua, as well as in the neighbourhood of Brisbane.

Flax was only being grown in Queensland in a small way, chiefly for seed for the use of dairy-farmers, but if winter rains fell the plant grew splendidly, and produced a longer straw even than that exhibited from Gippsland.

Mr. Pye emphasized the value of co-operation in fibre production. The silk industry in every country depended on the efforts of numerous small producers. The failure to produce good flax fibre was largely due to ignorance on the part of the growers. The sowing time was of much importance. In Northern Victoria flax should be sown in the autumn, and the proper preparation of the soil before sowing was also important.

Mr. Richardson stated that flax products were imported into Australia to the value of about £500,000 per annum. Only about £10,000 worth of flax products were produced in Australia. In 1907, a Commission was appointed to investigate the industry, with a view to encouraging it, but it had led to little result. Since that date the Commonwealth Government had paid to the grower 10 per cent. bounty on the value of the produce. In Victoria, the acreage under flax had varied from 190 to 1,200 acres in different seasons.

The fluctuation was due partly to the difficulty in securing labour and the uncertainty of the seasons, but particularly to the absence of knowledge as to the mode of treatment of the fibre and to the absence of a definite market. Prior to the war the fibre brought £45 a ton, now it was bringing about £120 a ton. If the industry could survive when the product was only worth £45 per ton, it should surely flourish now that the product was worth nearly three times as much.

Flax for seed might do in many parts of Australia, but for fibre a cool climate was required, such as that of Gippsland and Tasmania, and the rainfall required was 30 inches. At the present time the industry was almost entirely concentrated in the Drouin district.

In that district about $1\frac{1}{2}$ to 2 tons of flax straw per acre was the average yield. The flax miller gave £3 10s. per ton before the war, and was now giving £4 per ton; and the average return to the grower was between £6 10s. and £7 per acre.

TABLE SHOWING PRODUCE FROM 1 TON OF FLAX STRAW.

Produce.	Pre-war Prices.	£ s. d.	Present Prices.	£ s. d.
3 cwt. Linseed	At £14 per ton	2 2 0	At £24 per ton ..	3 12 0
$1\frac{1}{4}$ cwt. Fibre	At £45 per ton	2 16 3	At £120 per ton ..	7 10 0
$\frac{1}{2}$ cwt. Fine Tow ..	At £10 per ton	0 5 0	At £40 per ton ..	1 0 0
2 cwt. Coarse Tow ..	At £5 per ton ..	0 10 0	At £9 per ton ..	0 18 0
		5 13 3		13 0 0

At Drouin practically the whole of the crop is used for fibre as well as for seed. The manufacturer formerly paid £3 10s. for material which yielded him produce worth £5 13s. 3d.; now he is paying £4 for material for which he ultimately gets £13. This is a striking illustration of the need for co-operation among the growers to control the mill so that they may share in the profits due to increased prices.

There are no technical difficulties in growing flax; it is very similar to a hay crop, and the cost of production is very little more, about £3 15s. per acre. Two points must, however, be observed. First, the necessity for rotation. Flax grown continuously on the same land is a failure, as the land gets flax-sick. It should not be sown oftener than once in three or four years. Secondly, it must be sown early, April being the best time, since spring-sown flax was often a failure owing to climatic conditions.

He pointed out that this crop might well be taken up by returned soldiers under the repatriation scheme, in conjunction with the growing of hay or potatoes, or dairy-farming. It would be essential to secure cheap land, and to establish a co-operative mill, and if the prices kept up, success would be almost certain. On this latter point he would like to have Mr. Hogg's opinion.

Mr. Hogg stated that prices at present were still rising, and were likely to be enormous if the war continued. They would, undoubtedly, fall after the war, but he doubted whether they would ever again fall to pre-war figures, and even a fall of 100 per cent. would leave a considerable margin.

Referring to the figures given for the Drouin district, he said that $1\frac{1}{4}$ cwt. of fibre from a ton of straw was a very poor result, and should certainly be improved upon. The growers appeared to be going for both fibre and seed, with the result that neither was satisfactory. The fibre was dry and harsh and would never make fine linen, but even so, the Old Country would be glad to get it, and he suggested that the British Government should be asked whether they were prepared in 1919 to purchase any quantity of flax produced in Australia, say, 1,000 tons, and what price they would give. If the reply was satisfactory, a large area could be sown with flax next season, and the industry would be established for all time.

The farmer's business was to produce the straw. He could not be expected also to turn it into fibre, but he ought to have an interest in the result of the flax-mill.

The Sisal referred to by Mr. Quodling had been handled by his firm, and was a very fine sample. What a pity it was that they had not got a pest of Sisal instead of a Prickly Pear pest in Queensland!

Mr. McAlpine asked for information as to brush-fibres.

Mr. Hogg stated that good Sisal and good Aloe were used for this purpose. These were simply the hard coarse ends of the fibres, which were fit only for brushes.

He had omitted previously to mention Marine fibre (*Posidonia*), found in such quantities on the coasts of South Australia. He did not think it had a future. It had been used for mixing with wool, but even then the results were not very satisfactory.

Prof. Watt said that in view of New South Wales' experience, he was rather surprised at the optimism that had been expressed with regard to growing flax. It had been tried at all the Government Experimental Farms in that State, and had not been a success at any of them. The main object had been to produce linseed, but in no case was this a financial success, whilst the crop was not a good fibre-crop, except at Glen Innes, which was comparable to Gippsland in its rainfall. Several farmers had taken up the venture and given it up again owing to the fact that they had to treat the fibre themselves, there being no mill to send it to.

He asked whether the dark colour of dew-retted flax would detract from its value when exported. He would also like to hear Mr. Hogg's opinion as to the prospects of chemical-retting.

Mr. Hogg stated that the dark colour was characteristic of dew-retted flax, wherever produced. Dark flax was more difficult to bleach, but when it had been bleached it retained its lustre in a surprising way, standing washing better than water-retted flax. The latter was softer and was preferred by manufacturers, but they were always prepared to take dew-retted fibre.

Many experiments in chemical-retting had been tried, but none of them had been successful. Retting could be done in a bog, a running stream, or a tank, but by using chemicals you were endeavouring to hurry on a process where nature would not be hurried. His experience of these processes was most unsatisfactory.

Prof. Flynn stated that following on the Commonwealth bonus in 1907, a number of farmers on the north-west coast of Tasmania decided to grow flax, but they found that they had to do their own retting, and the experiment failed. He thought that district, however, from its climate and its proximity to Melbourne, should be a very favorable one for fibre-growing. He would like information as to whether flax-growing could be combined with potato-growing. The native flax in Tasmania suffered from a rather severe disease, which was transmissible to the cultivated flax, and he would be glad to know whether this disease had done any damage in Gippsland or elsewhere.

Mr. McAlpine said that there was grave danger of flax being infected with disease from the wild plant, though he had never known serious damage caused in this way. He thought that the wild flax should be destroyed as a safeguard wherever flax cultivation was undertaken.

Prof. Paterson said there was no doubt that the matter under discussion was of the utmost importance since, though owing to the high cost of labour we might not be able to compete with other fibres in the world's markets and on economic grounds it might be better to buy our fibres rather than grow them in Australia, there was very grave danger in being dependent on outside sources for our fibres in the event of war. The trend of the discussion seemed to show that flax was considered the most likely fibre-crop to succeed, but it was also fairly evident that for the production of fibre from this plant a cool, wet climate was necessary. The areas already indicated were the south coast of New South Wales, Gippsland, Southern Victoria, and Tasmania, and he would like to point out that the south-west corner of Western Australia had one of the coldest climates in the Commonwealth, and in parts the rainfall was over 40 inches.

Prof. Watt said that in New South Wales experiments were being carried out with flax under irrigation at Yanco. So far they had only two years' experience to guide them, and the crop was grown mainly for linseed. The plants grew to a fair height, however, and if fibre could be produced by irrigation, it would enlarge the possible areas where flax could be grown in Australia.

Mr. Sutton mentioned that some years ago flax had been grown in New South Wales for seed, but there was no market for the straw. He had ascertained that it could be utilized for the manufacture of brown paper, and for this purpose was worth £2 per ton. He thought that coldness of climate was not nearly so important as sufficient moisture. If the labour difficulty could be overcome, there would be a considerable area in Western Australia where flax-growing could be combined with potato-growing. He was optimistic because, although Mr. Hogg had clearly pointed out that the main difficulty was the labour question, he still advocated the growth of flax in Australia.

In reference to co-operation, he thought that farmers were increasingly realizing the necessity for this, especially in Western Australia, where this year they were handling the wheat crop by their own co-operative societies, whilst in other States this was done with butter. He thought there was no doubt that if flax-growing was started, they would be prepared to co-operate so as to retain the profits in their own hands, but they would have to recognise that they must be prepared to pay for good management.

Prof. Perkins said that so far no one had referred to the difficulty experienced in other countries in growing their own seed. Flax was grown in Europe, North Africa, and Asia Minor in a great diversity of climates, though in the hotter ones almost entirely for seed, it being found that a prevalence of cloudy skies was necessary for the production of fibre, as the direct rays of the sun were injurious. All these countries, however, found it necessary to renew their seed every other year from Riga, it being found that seed grown in countries other than Russia deteriorated after the second year. He could not help wondering whether we should have the same experience here.

Mr. Sutton suggested that it would be valuable to know what was the practice at Drouin.

Prof. Perkins stated that they grew their own seed.

Mr. Sutton thought that, perhaps, Tasmania could grow seed for the mainland.

With reference to *Phormium tenax*, he thought there were parts of Western Australia where it should do well, and he would like to know the average price per ton, and whether there was any difficulty in producing fibre from the leaves.

Mr. Hogg said the price was now £50 to £54 per ton; before the war it was £38 per ton. It was important to obtain the right variety of *Phormium tenax*. One or two leaves at a time were fed into a machine called a stripper, costing about £60 and treating 8 tons a week. After the leaves had been stripped they were well washed in a supply of running water, then put out to dry, and finally scutched. The scutching is very simple. In any part of Western Australia where there were swampy lands, well-drained in summer, the plant would be worth trying. If in three or four years the leaves ran up to 7 or 8 feet, there would be no reason why the industry should not succeed as well as in New Zealand.

Prof. Flynn stated that in Tasmania the drying of the leaves had proved a difficulty; the farmers had found it too much trouble.

Mr. Hogg said that in New Zealand the wet hemp was merely hung over wire fences and left to dry.

Prof. Paterson suggested that the dry summer of Western Australia might provide ideal conditions for drying the leaves, and should reduce the cost of production.

Mr. Hogg said he was not a great advocate of *Phormium tenax*; even in parts of New Zealand the fibre was too short. The best fibre came from Foxton, near Wellington. He thought the plant wanted plenty of water in winter, but could stand a dry summer, and that the dry summer in Western Australia should reduce the cost of production.

Prof. Paterson said he would endeavour to obtain roots to take to Western Australia for experiments.

A vote of thanks to Mr. Hogg for his address and the trouble he had taken in bringing exhibits and supplying so much information, was moved by *Dr. Green* and seconded by *Mr. Pridham*.

Mr. Hogg, in replying, expressed the hope that the discussion would lead to results in the near future, and emphasized the importance of co-operation among the growers.

THE AUSTRALIAN SUGAR INDUSTRY.

By Harry T. Easterby, General Superintendent, Bureau of Sugar Experiment Stations, Queensland.

PART I.—CANE SUGAR.

The problem of the Sugar Industry in Queensland, which supplies over 90 per cent. of Australian-grown sugar, is so many-sided and is governed by so many factors that it forms in itself a complicated study of no mean magnitude, and one which it is impossible to deal with completely in a paper of this length. The industry has also during late years been closely bound up with politics, both Federal and State, and this has not conduced to clear the situation.

In this part of my paper I propose to divide the subject under several heads, each of which will be dealt with as briefly as possible. These will include—

(*a*) Short History of the Queensland Sugar Industry prior to Federation.

(*b*) Review of the Industry since Federation.

(*c*) Scientific Work, Varieties of Cane, Cultivation, Soils, Pests, Milling Work.

(*d*) Comparison with other Countries.

(*e*) Labour and Wages.

(*f*) Health in the Tropics.

(*g*) Utilization of molasses.

(*h*) Present-day Problems. Foreign Settlement.

(*i*) National Importance of the Industry and need for Federal Protection.

(*j*) Expansion of the Industry.

(a) Short History of the Industry prior to Federation.

The Cane-sugar Industry in Queensland, like many others, commenced on an insignificant scale early in the history of the then Colony. This year (1917) it will produce more sugar than can be consumed in Australia.

It was stated in a Report on the Sugar Industry made in 1880 by Mr. Henry Ling Roth, to whom I am indebted for many of the following details, that as far back as 1823 Mr. Thomas Scott, under the patronage of Sir Thomas Brisbane, succeeded in growing sugar cane at Port Macquarie, in New South Wales, and manufacturing 70 tons of sugar. Mr. Scott worked hard, both practically and by ventilation of the subject in local newspapers, to prove that sugar could be manufactured in that Colony. In 1849 proposals were made for the formation of a sugar company in South Brisbane, and there is said to have been a small plantation at Eagle Farm, on the Brisbane River, but apparently no sugar was made. Sugar cane was cultivated in the gardens of several people in Brisbane about this time, and a considerable amount was also grown in the Government Botanical Gardens. The first sugar produced in Queensland, according to Mr. Walter Hill, at one time in charge of the Botanical Gardens, Brisbane, was made as follows :—Sugar cane was taken from the Botanical Gardens in December, 1859, and passed between two steel rollers. The juice was taken back to the Gardens, and about 6 lbs. of sugar was made in a copper vessel. The first sugar made in Queensland, however, of which there is any official record, was manufactured by Mr. John Buhot, in 1862. In 1863 Captain Louis Hope had 20 acres under cane on Ormiston plantation, near Brisbane, and that gentleman is generally conceded to be the father of the Queensland industry. In 1863 the London Society of Arts offered a medal for the first ton of sugar made in the Colony. The first sugar-cane plants were most probably imported from Java and Mauritius, and about this time the Queensland Acclimatization Society took active steps in bringing over a large number of varieties. A tremendous impetus was given to the industry when land was made available for some years by the Government on remarkably easy terms for sugar growing, and in 1865 as much as 18,290 acres had been taken up for cane planting. Shipments of cane were this year made to New South Wales farmers for planting.

The early stages of the industry were almost entirely devoted to the production of cane, and the extension of land under cultivation. In 1866 so great was the demand for plants that there was actually a scarcity of cane for planting.

By the end of 1867 there were nearly 2,000 acres under cane, and six mills had been erected which between them manufactured 168 tons of sugar. There was, however, an insufficiency of mills, which caused heavy losses to the farmers, but mill-owners did well, as they could buy cane for 4s. a ton.

Up to this time the industry had been carried on entirely in Southern Queensland, but it now began to spread to Bundaberg, Mackay, the Herbert and Johnstone Rivers, and Cairns. It is in these places to-day that almost the entire output is manufactured, the extreme southern districts making very little.

Sugar growing continued to prosper, more land was brought under cultivation, and steam mills quickly superseded the antiquated cattle and horse power erections.

In 1875 a disease termed " rust " broke out in the cane. This, combined with an excessive rainfall, fell like a thunderclap on farmers, and brought ruin to many of them. The financial institutions became alarmed, and refused to render further aid. Planters, however, were too energetic to let their estates go out of cultivation. The variety affected was known as the " Bourbon " cane, but it was noticed that small patches of " Rappoe " or " Rose Bamboo " were not touched. Those who survived the blow commenced the cultivation of this variety, and confidence was soon restored, though many plantations changed hands. During 1879 and 1880 a rush set in for Queensland sugar lands, and plenty of capital was made available. The production of sugar in 1870 and 1880 is given as follows :—1870, 2,854 tons ; 1880, 15,681 tons.

During the next decade, 1881 to 1890, the production of sugar in tons varied from 16,660 to 68,924, and from 1891 to 1900, 51,219 to 163,734. During the period under consideration a large number of small mills were erected in most of the sugar-growing areas of the State, as well as many large factories. On the decline of prices owing to the stimulation of bounty-fed sugar in Europe, most of the small mills went under. During this time, also, a number of modern mills were erected under the Sugar Works Guarantee Acts, with capital found by the Queensland Government. These were known as "central mills," and led to a further reduction in the small privately-owned mills. In 1901 there were some 60 sugar-mills in existence in Queensland.

From 1863 to the advent of Federation in 1901, the Sugar Industry was almost entirely carried on by labour from the South Sea Islands. This class of labour, while eminently serviceable and of great use in opening up the country, was always distasteful to the majority of Australians, and when Federation took place steps were taken to make the industry entirely a "white" one. This was accomplished by passing a measure prohibiting kanakas entering Australia after 1904, and providing for the deportation of those who had already been engaged within a certain period. This only left some 2,000 kanakas in Queensland, the majority of whom had resided for years in the State and had married. About the same time the Federal Excise Act came into operation, which provided for an import duty of £6 per ton on all foreign sugar. An Excise duty was collected on sugar manufactured in Australia, and a rebate was given to that in which white labour was used.

(b) Review of the Industry since Federation.

Since the establishment of the Commonwealth a great change has taken place in the Queensland Sugar Industry. Recognising the trend of events, the large planters (who were in many cases millers), and who had not previously cut up their lands, did so now, which led to the settlement of a further number of small farmers as cane growers. This had been accomplished to some extent already by the State Government's encouragement of the building of central mills. The colored labour previously employed in the industry has been almost wholly replaced by the white races. The sixteen years that have elapsed since Federation have seen a further decrease of the small uneconomic mill and a general increase in the efficiency and management of the larger surviving mills. This has been followed by the growing of better varieties of cane by the farmer, and a general improvement in the tonnage of cane and sugar per acre grown by improved methods of cultivation. At the end of 1916 the number of sugar mills was 45. This included three new large and thoroughly up-to-date mills erected since 1913, viz., Inkerman, Babinda, and South Johnstone. The first of these is in the Lower Burdekin district, south of Townsville, and is the property of Messrs. Drysdale Bros. The Babinda and South Johnstone mills have been erected by the Queensland Government to develop the rich tropical lands south of Cairns. These two mills, which are the latest word in sugar-crushing plants, cost in all £754,000.

The output of sugar has steadily increased in normal years. Drought years, of course, reduce the average output. The yield of sugar produced yearly in Queensland since 1901 is as follows :—

Year.	Tons Sugar.	Year.	Tons Sugar.
1901..	120,858	1910	210,756
1902..	76,626	1911	173,296
1903..	91,828	1912	113,060
1904..	147,688	1913	242,837
1905..	152,722	1914	225,847
1906..	184,377	1915	140,496
1907..	188,307	1916	176,973
1908..	151,098	1917	340,000 (approximate)
1909..	134,584		

Queensland now produces above 91 per cent. of the total yield of sugar in Australia.

Since Federation to 1915 the average shortage between the production of sugar by Queensland and New South Wales may be set down at 45,000 tons. This has been due first to the uncertainty that prevailed at the time of the transition period, during which white was being substituted for colored labour, secondly to climatic drawbacks, and thirdly to the fact that all the mills in Southern Queensland have not during the past ten years been supplied to more than 52 per cent. of their full capacity, while more cane could also be grown for some of the northern mills if the future of the industry were assured.

Of the 45 mills above referred to, 6 were owned by the Colonial Sugar Refining Company, 15 were Central Mills, erected by the Government, and the remainder were mills owned by private persons or companies ; included in the latter class being all the remaining small mills, *i.e.*. those whose capacity was 15,000 tons of cane and under.

The amount of capital invested in factories and farms is now stated to be some £9,000,000.

(c) Scientific Work, Varieties of Cane, Soils, Cultivation, Pests, Milling Work.

The Government of Queensland (which has naturally always taken a warm interest in the sugar industry) in 1900 established a Bureau of Sugar Experiment Stations. This institution has at present two Experiment Stations, one at Mackay and the other at Bundaberg, while a third is about to be established in the Johnstone River sugar district, near Innisfail. Laboratories are established at which soil investigations are undertaken, and analyses of fertilizers, limestones, waters, sugar canes, and sugar-mill products are carried out for growers and millers. The introduction of new varieties of cane from other countries is a part of the Bureau's work, and their testing upon commercial lines both in the field and laboratory entails a great deal of patient investigation. In addition to this, experiments in cultivation, rotation, fertilizing, and irrigation have been and are still being carried on, and the results are published yearly in the Annual Report of the Bureau.

A large number of the varieties of cane introduced in recent years were brought from the adjacent island of Papua. Many of these are stated to be growing in the gardens of the natives, where they are used for eating purposes at their festivals.

The best variety of cane brought into Queensland so far is a New Guinea cane with the name of Badila. This was introduced by the Department of Agriculture through one of its officers (Mr. H. Tryon, Entomologist), who in 1895 visited Papua and secured some 66 varieties. It is an exceedingly rich cane, with a small percentage of fibre. The following is an analysis :—

Brix, Total Solids.	Per cent. Sucrose in Juice.	Per cent. Glucose in Juice.	Per cent. Sucrose in Cane.	Quotient of Purity.	Available Sugar.
22·6	21·4	0·21	18·6	95·0	17·85

Queensland has always been well to the front in the introduction of new varieties. It is estimated that prior to 1904 some 500 different kinds of canes had been brought from other countries. From 1905 to 1916, 360 new varieties, largely from New Guinea, were introduced to the Mackay Sugar Experiment Station. Of these, a large number have been tested, and canes suitable for distribution have been selected. The methods of selection are to grow the canes over a period of years and over a number of ratoon crops, each variety being analyzed no less than four times in each year, during the months of June to September. Those showing high percentages of sugar which have proved good croppers, and are absolutely free from disease, are made available for farmers and plantations. Others, light in weight and difficult to cut, being valueless from the farmer's point of view, were discarded, as were others which developed disease. The results obtained from carrying five of the original New Guinea varieties collected by Mr. Tryon, over a plant and five ratoon crops, are summarized in the following table :—

No. or Name of Variety.	Country.	Total Cane per Acre. English tons (Six Crops).	Total Sugar per Acre. English tons (Six Crops).
15 (Badila)	New Guinea ..	270·5	50·2
24	" ..	255·1	46·3
24A	" ..	266·7	45·6
24B	" ..	257·5	42·2
40	" ..	253·4	38·8

In addition to the varieties introduced from other countries, a large number of seedlings grown from the actual seed in the cane have been raised by the Queensland Acclimatization Society and the Colonial Sugar Refining Company. As is usual in seedling work, very few of these were of commercial value, but a cane known as Hambledon Queensland 426 raised in this way by the Colonial Sugar Company is to-day extensively grown, and is of high sugar content. At the present moment there are some 40 varieties being grown by cane farmers for the mills, but the standard cane in North Queensland is the Badila previously referred to. In Southern Queensland a seedling cane known as Demerara 1135 is the favorite variety.

Soils.

The land in Queensland used for sugar growing is included in a long, narrow, coastal belt. Parts of this belt are separated from each other by considerable tracts of non-sugar country. The latter, owing to deficient rainfall or poorness of soil, are not utilized for cane. This belt is included between latitudes 16° and 28° south, and the bulk of the staple is grown within the tropics. Cane soils vary considerably in character and composition. The following classification was made by Dr. Maxwell, formerly Director of Sugar Experiment Stations :—

District.	Soils.
Cairns ..	Partly shaley sterile soils, but in the main, deep alluvial sandy loams, also rich red volcanic soils.
Mackay ..	Shaley in parts, with better alluvia over the lower levels. Mixed volcanic and rich siliceous alluvia.
Bundaberg ..	Rich alluvial delta soils, interspersed with sterile soils and deep rich red volcanic soils.

The bulk of the sugar soils can be stated to be from good to rich alluvial, such as river flats and the deep red volcanic soils of considerable depth. The nature of the country is generally designated "scrub" and "forest." The North Queensland scrubs are really jungles, carrying a thick growth of what is known as scrub timber, such as silky oak, bean, pender, kauri, milkwood, Johnstone River hardwood, interlaced with lawyer vine and other creeping plants, while the stinging tree is also conspicuous. Forest country usually consists of ironbark, bloodwood, Moreton Bay ash, bluegum, poplar-gum, and acacia.

The following are average analyses of a number of soils from each of the three sugar districts mentioned :—

District.	Lime.	Potash.	Phosphoric Acid.	Nitrogen.
Cairns	·292	·310	·141	·122
Mackay	·829	·223	·165	·122
Bundaberg	·636	·144	·404	·120

Rainfall.

The Queensland rainfall, fortunately, is highest during the summer period, at which time the cane plant makes its maximum of growth. The following are average rainfalls in the principal sugar-growing districts :—

Cairns	92·65
Johnstone River	160·88
Herbert River	84·91
Mackay	66·67
Bundaberg	44·40

Cane grows best when the relative humidity of the atmosphere is high, and this is the case during the wet season in Northern Queensland.

Pests.

The sugar-cane plant in Queensland is subject to many pests and diseases. The most serious of these at the present time is the grub pest. The larvae of *Lepidiota* and other scarabaeid beetles attack the roots of the cane, causing the stool ultimately to fall and perish. Thousands of tons of cane, particularly in the north, have been destroyed, and a high price, per lb. or quart, is now paid for the grub and beetle in many parts of Queensland. In Mackay over 15 tons of beetles have been captured within so short a time as two months and destroyed. The weevil borer (*Rhabdocnemis obscurus*) and the moth borer (*Diatraea saccharalis*) do a certain amount of damage, but have not so far called for urgent repressive measures.

Investigation and research work is now being carried out by the Bureau of Sugar Experiment Stations in a systematic way. The Entomological Laboratories are situated at Meringa, near Cairns, which is the centre of the worst grub-infested region in the north. The work is in charge of Dr. J. F. Illingworth, formerly Professor of Entomology at the College of Hawaii. Numerous Bulletins dealing with the question have already been published, and work now being undertaken will include :—

Morphological study of reproductive organs of beetles, with relation to the period of ovipositing and the number of eggs produced.

Morphological study of the fungus parasites.

Breeding of the various local parasitic and predaceous insects in cages.

Introduction and breeding of beetle parasites from other countries.

Experimental methods for the rapid multiplication and wide distribution of our fungus parasites.

Introduction of bacterial and fungus enemies of the beetles from other countries.

A further study of various light-traps for the beetles.

A further study of repellents

Field and laboratory experiments in the use of poisons for the grubs.

Field experiments to determine the relation of fertilizers to resistance ; using green manure, stable manure, meatworks' refuse, nitrate of soda, &c.

Milling Work.

During the past twenty years a great improvement has taken place in mill work and the coefficient of work and recovery of sugar is now much more satisfactory, although there is still room for better work. The average tons of cane required to make a ton of sugar has dropped from 9·54 in 1899 to 8·5 in 1914, while in 1915, owing to the high density of the cane caused by a dry season, it fell to 8·2. Seeing that the up-to-date mills in Hawaii take 9·16 tons of cane to 1 ton of sugar, the above results compare more than favorably with that place. Taking one of the Central Mills (Mulgrave) in the middle of the season, we find the extraction per 100 of sugar to be 94·10 per cent., the recovery from sucrose in cane to be 82·2, the commercial cane sugar in cane 13·7, the tons of cane to 1 ton raw sugar 7·88, and the quotient of purity of the final molasses 37·4. Chemical control is practised in all the sugar mills except those of very small dimensions. The regulation of the price paid for cane is vested in a State Board, consisting of five members, called the Central Cane Prices Board, which fixes the prices for the current season before it commences. Local Boards also sit in the different districts, and if they fail to make an award the matter is relegated to the Central Board.

The best work is done by the Colonial Sugar Refining Company, who inaugurated chemical control in their factories many years ago. Their system is a very complete one, and enables the management to lay its finger quickly on preventable losses. In the north this company frequently turns out 1 ton of sugar for between 6 and 7 tons of cane.

(d) Comparison with other Countries.

The growing of sugar cane in Queensland compares favorably with other countries when it is remembered that with slight exceptions it is carried on by a large body of small farmers (about 4,000), who do not possess the necessary capital to develop their farms in the same manner that the large millers of Hawaii and Java can do, with the added advantage in the latter island of remarkably cheap labour. Not only is Java blessed with a good supply of labour, but its irrigation works are of great magnitude, and the waters are rich in a silt containing potash and phosphoric acid (stated by Prinsen Geerligs to be quite sufficient for the cane crop), so that only nitrogenous manures are needed. Add to this that the imperative needs of a large native population demand a carefully regulated system of land tenure so that cane is only planted one year in three This means that there are only crops of plant cane in Java, no ratoons.

In Hawaii enormous sums are spent in irrigation and manures, it being considered that at Ewa plantation alone £14 per acre is expended on the former, which expenditure is estimated to give a return of 3 tons of sugar per acre more. The total capital invested in Hawaii in irrigation plants is stated to be £3,000,000. The crops in Java average about 40 tons per acre, while those of Hawaii are given at 44 tons of cane and 4·9 tons of sugar per acre, a very fine result. In Queensland in favorable seasons in the north 50 to 70 ton crops of plant cane are common, but the average is pulled down by the want of proper cultivation and fertilizing in some instances, drought and frosts in southern sugar districts, and the ratoon crops. The latter are the canes that grow up again after the plant crop has been harvested, and third and fourth ratooning is practised in Southern Queensland. In the north it is rare to go beyond second ratoons. The cane per acre of recent years has averaged about 20 tons, which is better than it was some time ago. The varieties of cane in Queensland are, as a whole, better than in either Java or Hawaii, as they are higher in sugar percentage. Mill work in the best factories in Queensland is quite as good as elsewhere, but a number of mills require bringing up to date, and their efficiency should be increased. This, at the present time, is impossible, owing to scarcity of freight and the difficulty in obtaining machinery.

(e) Labour and Wages.

Owing to the recent awards made by the Industrial Court in Queensland, the Sugar Industry in that State is probably the highest paid agricultural industry in the world. Australia is the only country in the Globe that is attempting to grow cane sugar with white labour, and the experiment is an interesting one, not only to ourselves, but to other sugar producing countries.

because (as Dr. Maxwell pointed out in 1905 in a report to the Commonwealth Parliament) "it traverses natural and economic conditions that have to be consulted at every step." It is noteworthy that seven years after this was written the Federal Royal Commission upon the Sugar Industry stated there appeared to be no reason to doubt that white labourers can satisfactorily perform all the work of the sugar fields, and that was a view founded upon accomplished facts.

It must be admitted that so far the employment of white labour has meant a great increase in the settlement and prosperity of the Queensland coastal towns, such as Bundaberg, Mackay, and Cairns. The kanakas were of little value to the towns, their wages and wants were small, and their standard of living low. Work in the cane-fields such as hoeing is now paid at the rate of 1s. 5d. per hour in the south to 1s. 7d. per hour in the north, or 11s. 4d. to 13s. per day of eight hours. Cane-cutters during the season are paid from 15s. 6d. per day in the south to 16s. 8d. in the north. The bulk of this work, however, is done on contract, and cane-cutters receive 6s. 3d. per ton for crops of 15 tons per acre and over in the south, and 6s. 9d. for the same tonnage in the north. Good cane-cutters can earn up to £10 and £12 per week at these rates. Overtime is paid for at the rate of time and a half, and Sunday work is at double rates. Twelve days are specified as holidays, on which overtime rates have to be paid. Since 1912 wages have increased 60 per cent. in the industry. It is only in a year like the present, when crops are exceptionally good and the price of sugar is higher than ever before, that farmers can hope to pay such rates. Labour is stated to represent about 70 per cent. of the cost of the production of cane. It is, however, generally recognised that the payment of a fair and just rate to labourers is essential, and that it makes for increasing efficiency. No grower of cane begrudges this to labour so long as he obtains such a price for his product as will enable him to pay it and the labourer puts in a fair day's work. The greater portion of the cane-cutting is carried out by seasonal labour obtained from New South Wales, Victoria, and Tasmania, and the cutting season lasts from four to six months.

(f) Health in the Tropics.

The Federal Royal Commission stated in their report that they entertained no doubt as to the possibility of effective settlement by a white population of the Queensland coastal areas. The present population is a normally healthy one, with a fully developed physique, and a low death rate. In evidence given before the Commission, the head-mistress of the State school at Mossman stated: " . . . . the general standard of health and physical standard here are as good or better than they were in the west. . . . The attendance is better than on the Darling Downs. Only two children who have been in attendance at the school have died since I have been here (13½ years). . . . Neither of them was born in the district."

Dr. P. H. Clarke, Government Medical Officer at Port Douglas, stated, *inter alia*, "that cases of sunstroke were rare; that epidemics were attended by a lower mortality than in the southern portions of Australia; that, with proper care, the probability of children born in the district living to adult ages was greater than in the southern portions of Australia; that the most prevalent cases of tropical complaints were preventable."

The opinion held by medical men is that the white man can lead a healthy life and rear a vigorous family in tropical Queensland provided he adapts himself to his surroundings as regards diet and clothing and avoids alcoholic excesses, which are debilitating in the tropics, and a fruitful cause of sickness amongst the workers in the Sugar Industry.

The effect of the Northern Queensland summer climate is more enervating in respect to women than men, and they require more frequent changes, while conditions should be rendered fit for white women. Dr. Maxwell, in his report to the Federal Government, said : "The white woman is rendering a tribute in populating and settling the north, which commands the greatest praise, but also the gravest concern ; and whatever of the nature of alleviation can be brought in or retained in the form of domestic aid to lessen the physical strain put upon her by the climatic situation, should be done even if it is done for no higher than economic reasons."

The winter climate of Northern Queensland is delightful, while the southern parts are cold and frosts are often experienced. At the back of Cairns is the invigorating Atherton Tableland, which is within an hour or two by rail from the hot moist seaboard, and which affords to coastal residents a complete change.

(g) Utilization of Molasses.

The chief source of waste in sugar-mills is that of molasses. It is estimated that more than one-third of the total output is run away. In the last report of the Government Statistician of Queensland, he gives the figures for 1916 as under :—

Total quantity recorded	6,432,439 gallons.
Sold to distilleries and others	818,812 ,,
Used for fuel	433,500 ,,
Used for manure	54,600 ,,
Used for feeding stock	1,439,108 ,,
Held in tanks at mills	797,084 ,,
Balance run to waste	2,799,335 ,,

Approximately 11,000,000 gallons have been wasted during the past five years, and he says that the quantity shown as run to waste would be very much larger if all mills furnished full details of their production.

The Commonwealth is establishing a factory on the Brisbane River to treat molasses and lime with a view to making acetate of lime. This will be afterwards converted into acetone, which is used in the manufacture of cordite.

This amount of molasses run to waste opens a field for enterprise if the freightage costs from the mills can be overcome, and is one that might be profitably discussed by this Conference. Proposals have been made for its conversion into motor and industrial spirit, but nothing concrete has yet been done.

(h) Present Day Problems.

Queensland expects to produce this year upwards of 300,000 tons of sugar, which will be far in excess of the yield of any previous year and of the Australian consumption. No doubt this could be profitably exported in view of the high rates for sugar ruling in Great Britain, but for two reasons. The first is that an embargo has been placed on export, and, secondly, if this were removed it is doubtful if bottoms could be obtained in which to ship the surplus. This will probably, therefore, have to be held by the Commonwealth to make up for a possible shortage next year. The most acute problem facing the Queensland Sugar Industry to-day is its uncertainty. If a fair price is maintained the industry will go on. If not, it is doomed to failure. After the war, when huge stocks of sugar are released, there will be a slump in the world's prices, and the southern people, overlooking the national importance of the Queensland Sugar Industry, may clamour for cheap sugar. If Australia is going to keep the Queensland Sugar Industry for the white races, it must be prepared to pay such a price for sugar as will enable this to be done. The Federal Royal Commission said, "a white community which prefers to grow its own sugar in its own territory with white labour must face the responsibility of making good the increased cost of production under the higher standard of living and reward. Either the consumer or the taxpayer must pay."

These difficulties, which are only lightly touched on here, are having another effect in some northern sugar districts. They are leading to a determination on the part of certain Queensland cane growers to get out of the industry, and the opportunity to do this is being given them by the keen desire of Italians and other foreigners to become possessed of sugar farms. In given localities in the north, principally the Johnstone and Herbert Rivers, the proportion of foreign labour is from 75 to 90 per cent., the Italian nation being the most largely represented. It is principally from this latter class that the offers to buy cane farms are coming. Their methods are for several of them to put their earnings together and pay a deposit on a farm, and then to place one of their number in to run it. The remainder go on working in the cane-fields until they have saved enough to pay a fresh deposit, when another Italian goes in. It is perfectly safe to say that 99 per cent. of the sales of cane farms upon the Herbert River recently have been made to Italians, whose standard of living is very much lower than that of our own race. Thirty per cent. of the total farmers on this river are stated to be of Italian nationality. At Mourilyan 26 out of 80 farms are in their possession to date, and they are also acquiring farms on the South Johnstone.

(i) The National Importance of the Queensland Sugar Industry.

The Royal Commission upon the Sugar Industry appointed by the Federal Government made use of the following pregnant words in their Report:—

> The problem of the sugar industry to-day is not, save in subordinate respects, a problem of industry, of wealth, or of production; it is primarily and essentially a problem of settlement and defence. No nation can afford to regard lightly the development of its industries, the progress of its wealth, or the economic efficiency of its productive machinery. But, important as these things undoubtedly are, they rank, as regards the sugar industry, on an inferior plane. The Commonwealth to-day is brought face to face with one of the gravest problems that has ever taxed the ingenuity of statesmanship—that of the settlement of tropical and semi-tropical areas by a white population living under standard conditions of life. And intimately associated with this problem is the question of national defence.

If the ideal of a White Australia is to become an enduring actuality, some means must be discovered of establishing industries within the tropical regions. So long as these regions are unoccupied they are an invitation to invasion as well as a source of strategic weakness. Granted so much, it follows that the supreme justification for the protection of the sugar industry is the part that the industry has contributed, and will, as we hope, continue to contribute to the problems of the settlement and defence of the Northern portion of the Australian continent. The recognition of the nature of this supreme justification is the first condition of a sound public policy in relation to the sugar industry. Relatively to it all other issues are of minor importance.

This statement as to defence has been justified by the fact that one in eight of the entire population of Mackay have enlisted to defend our country, over 3,000 have enlisted in Bundaberg—a similar proportion, and about the same proportion in Cairns. Had the rest of Australia enlisted in the same ratio we should have had over half-a-million men. As an instance of what can be done in settlement by the establishment of a mill in a new district, we may take the example of the recently erected factory at South Johnstone. Three years ago this locality was tropical jungle, now there is a large mill capable of treating 150,000 tons of cane, a township containing school, post-office, railway station, boarding-houses, picture shows, and upwards of 100 farmers settled on the land growing cane.

It was further pointed out by the Royal Commission that, as a result of the increase of the white population on the Queensland littoral, a new stimulus had been offered to the opening up and settlement of large inland areas at an elevation above sea-level.

After considering the necessity for erecting further mills in Queensland last year a Board, of which the writer was a member, said in its report to the Government:—

The settlement of our northern littoral appears to be indissolubly linked up with the expansion of the sugar industry. There is no present prospect of the establishment of any other industry on a considerable scale. Of rich tropical lands awaiting development there are large areas. The importance of the industry as a means of settling these lands and as the source of abiding wealth to the community cannot be overstated ; and, if this work is to be carried out, those engaged in the industry are entitled to expect and to receive the most sympathetic consideration from the people and Government of the Commonwealth.

It is beyond dispute that the expansion or even the continuance of the greatest agricultural industry in Queensland is impossible in the face of a hostile or apathetic public in the Southern States.

If we are to judge by the action since the commencement of the war of the Price-fixing Boards appointed by the Governments of New South Wales and Victoria—which in 1914 represented the two great political parties—public opinion in those States is not yet alive to the national importance of encouraging the industry. In 1914, taking advantage of a temporary fall in the price of sugar just prior to the declaration of war, these Boards fixed the wholesale selling price of refined sugar at £21 per ton, regardless of the fact that this was much lower than the average price of the previous three years.

The consequence to the industry of this action of the two Boards was thus dealt with in the writer's Annual Report of the Bureau of Sugar Experiment Stations in 1914 :—

It was found that the Queensland production of sugar, instead of being stimulated and encouraged, was being retarded by the unduly low price fixed by the Southern Control of Prices Boards in those centres of population where the bulk of the staple is consumed.

This led, in many cases, to mills making an absolute loss on the season's operations, and forbade the farmer obtaining that increase in payment for his cane to which he was justly entitled in order to meet the higher cost of production and the increase in the cost of living. This happened at a time when the price of sugar had been materially enhanced in the other sugar-producing countries, particularly in those employing cheap coloured labour. It was a position directly antagonistic to the white-labour ideals of this country and the national view of settling the Northern littoral, by means of the sugar industry, for defence purposes.

The Board went on to say :—

It was only by putting into operation the Sugar Acquisition Act of 1915—a purely war measure—that the Government of Queensland were able, with the assistance of the Commonwealth, to acquire the whole crop at a price which, though considerably lower than the world's parity, yet secured to the miller and the cane-grower a better return than was possible under the price fixed by the Southern Boards, without at that time increasing the cost to the small consumer. Even now sugar is obtained by the consumer for much less than the price that is being paid elsewhere, with the single exception of New Zealand, which imports black-grown sugar from Fiji duty free.

The co-operation of the Commonwealth Government in this transaction is proof that the National Government may be relied upon to take a wider and more national view of the question than the Governments of States in which sugar is not produced to any considerable extent.

With the close of the war the Sugar Acquisition Act of 1915 will automatically lapse, but price-fixing by Government Boards may continue, and, unless there is some agreement come to by the various Governments concerned, the Queensland sugar-growers and millers—and the latter include the Queensland Government—again will be at the mercy of Southern consumers. Any slight pecuniary benefit to the Southern people would be dearly bought if the effect were to jeopardize the prosperity or the very existence of the Queensland industry and drive a national product out of competition in the Australian market.

But it is not so much such action—which would be in direct conflict with that federal spirit which is supposed to animate the people of every State—that we have to fear as the insufficiency of the import duty. The present price of raw sugar can only be maintained, after the return of peace, by Commonwealth co-operation.

The import duty is at the very foundation of the stability of the industry. The President of the Australian Sugar Producers Association in giving evidence before our Board said :—

But for the home production in Australia we should at present prices have to send £7,000,000 to countries which would take practically nothing from us in return. That is a very large sum in one year, and if you multiply it by a few years, it is not very long before it amounts to £50,000,000, and if this country were £50,000,000 poorer, it would make a very big difference to the general prosperity of the whole of the Commonwealth. It is generally estimated that the sugar industry, directly and indirectly, in Queensland supports 100,000 persons, or one-sixth of the population, and any one can see that if the industry were to go to the wall it would mean the disruption of the whole industrial fabric. I do not think it is possible to over-estimate the importance of the sugar industry to this State or to the Commonwealth, because there is no doubt that without it it would be impossible to settle our tropical areas, and the day may come—we do not know what the future holds for us—when we shall have to prove our title to our tropical lands, and the only title under certain conceivable circumstances that would be accepted would be its effective occupation. That is taking a very wide and high point of view, but still we do not know what eventualities may arise, and we have to be prepared for them. The only way in which we can assert our title to this grand country is by occupying it effectively, which, of course, means making use of it.

As showing what the industry means in the distribution of wealth, the following statement was prepared by Mr. Gibson, one of the owners of Bingera Sugar Plantation :—

> I claim that the industry requires the utmost consideration from our legislators, in view of its great value to the Commonwealth. The following statement shows what one plantation and sugar mill means to the public in trade :—Revenue to railway per annum, £7,000 ; shipping company freights, £6,500 ; harbor dues and wharfage, £1,000 ; firewood cutters, £2,000 ; merchants' accounts, £13,000 ; foundry, £4,000 ; saw-mills, £1,500 ; cattle purchased for beef, £5,000 ; horses bought, £1,500 ; corn, £3,500 ; other produce, £1,000 ; lime, £300 ; flour, £1,500 ; coal, £1,000 ; wages, £45,000 ; cane cutters' contracts, £21,000 ; railway lines, permanent, 22 miles 2-ft. gauge, 8½ miles 3 ft. 6 in. gauge ; portable, 10 miles 2-ft. gauge ; locomotives, 6 : increased value of land to farmers by railway and river bridges past six years, £10,000.

The crop this year in Queensland will, if it be all cut, be worth about £7,000,000, at £21 per ton for raw sugar, and about £9,500,000 for the refined marketable output.

Summarizing the foregoing, it is evident that the present uncertainty as to the future of the Sugar Industry should be removed, and a well-considered scheme evolved which would have the effect of retaining the present white population in the coastal districts, and adding to their number as the increase in the consumption of the staple warranted. To the writer's mind, a recommendation of the Royal Commission was a good one—

> That the Customs duty on sugar, raw and refined, should fluctuate in accordance with foreign market prices—falling as those prices rise, rising as those prices fall

If the present high cost of production is to be maintained in the Sugar Industry, then the measure of protection afforded will need to be adequate.

(j) Possible Expansion of the Industry.

Although Queensland may produce a surplus of sugar this year, she has only once before in recent years been within measurable distance of the consumption of Australia. This was in 1913, when 242,837 tons were produced, making with the New South Wales production 265,000 tons, or equal to the then consumption. This is at the present time considered to be 265,000 tons, or 114 lbs. *per capita*. Owing to climatic drawbacks, however, a full season is impossible every year, and moreover the consumption of sugar is stated to be increasing at the rate of 5,000 tons per annum. If the industry be placed on a sound footing and the remainder of the rich tropical lands developed by sugar growing, the question may arise as to the disposal of surplus sugar when made. There are estimated to be 500,000 acres of land in Queensland upon which cane could be grown ; at the present time there are roughly 167,000 acres under cane.

Two suggestions regarding exportation of sugar have been made both of which are somewhat visionary :—

(*a*) Imperial Federation, which would protect sugar grown within the Empire by levying duties against outside countries ; and

(*b*) Payment of an Export Bonus by the Commonwealth or raised by a tax upon the Australian consumers of sugar.

A conference was called last year by the British Empire Producers Association, at which the Australian industry was represented by Mr. G. H. Pritchard, Secretary to the Australian Sugar Producers Association. The Conference framed an Empire sugar policy by recommending preferential treatment with total prohibition of enemy sugar for five years, and thereafter a 50 per cent. surtax. At no time should the difference between enemy sugar and Empire sugar be less than 1d. per lb. It is difficult to see how these recommendations would help the Australian production of sugar under white-labour conditions, although a suggestion has been made that all Empire sugar should be pooled, when the higher price of the small quantity of Australian sugar would only slightly affect the price of the whole Empire sugar to the British consumer.

PART II.—BEET SUGAR.

I do not propose to deal at any length with the Beet Sugar Industry, because it has not for one moment the same claim on Australia from the national stand-point as the Queensland cane industry, and it is for this reason that I have said nothing about the cane industry in New South Wales. Both these States are comparatively thickly populated, and if cane or beet growing were discontinued it would make very little difference to the population. If the cane industry in Queensland were to collapse the northern coastal areas would speedily become depopulated, and the ruin of several fine northern towns would be accomplished. As long as sufficient sugar can be produced in the tropical areas of North Queensland, there is no need for any special encouragement of sugar beet growing in other parts of Australia, important as it is as an agricultural industry from the stand-point of intensive culture, rotation, and the feeding of cattle.

For the present then the beet sugar question can be very well left to the demonstration being made at Maffra, as it is not likely that private enterprise will provide capital for beet sugar growing until it is proved that the industry will be a payable and successful one. The Federal Royal Commission previously quoted went further than this, and said that if its advocates were right as to the relative economic efficiency of the beet industry, encouragement by the Commonwealth must imperil the very existence of an industry which has been built up at a great expense to the Commonwealth and the State of Queensland, and which, as a contribution to the solution of the problems of tropical settlement and defence, serves purposes of which the importance to our national life can scarcely be exaggerated. They recommended, therefore, for consideration whether it would not be advisable to pass an Excise Act imposing a special Excise of £2 per ton on the manufacture of sugar from beet in any year when the total output of beet sugar within the Commonwealth shall exceed 10,000 tons. Before concluding this paper, a very brief account of the industry in Victoria may be interesting.

The history of the beet-sugar movement in Victoria has been rather an unfortunate one up till quite recently. Before the establishment of the Maffra Factory attempts were made to grow beet at Anakies, near Geelong, and a factory was actually built at Rosstown which never operated. The erection of the Maffra Factory was the result of an "Act to encourage the establishment of the Sugar Beet Industry in Victoria." Money was lent by the Government, and operations were commenced in 1898. At the end of the second season the factory shut down, its two campaigns having proved unsuccessful for lack of beets. The Government foreclosed on its security, and the factory remained idle for some eleven years. The Government then reopened the building, and it has since 1911 been working, for the first years at a loss. Last season 15,159 tons of beets were cut, less than half the capacity of the factory, which is a fine one. This yielded 1,948 tons of white sugar. The acreage harvested was 1,320. After paying all expenses, including interest and depreciation, a profit was made of £8,013 13s. 2d., which is decidedly the best result to date. Unfortunately, the beet industry in Australia has to depend on foreign countries for its seed, and there has been some difficulty experienced this year, which will probably cause a loss of acreage for next season.

The two difficulties experienced in the Maffra district are (*a*) climatic conditions and (*b*) want of interest by the farmers. Even at the present time there are comparatively few farmers growing beet, and a large part of the supply is from one large estate which is rented out to smaller growers who have no land available of their own. This is quite contrary to the European practice of improving one's own land by the growth of sugar beet.

The benefits to be derived from growing beets are patent. It encourages closer settlement, and, like the cane industry, causes large sums of money to be circulated in the payment of wages and purchase of materials. It considerably enriches the land and the pulp produced is exceedingly valuable in stock raising. Australia, however, must develop her unoccupied spaces first, and when this is accomplished, and the needs of Australia demand a greater sugar production, the beet industry will find room for its establishment.

Discussion of Mr. Easterby's Paper.

Prof. Watt thought that Mr. Easterby had made out a very good case for giving special encouragement to the Queensland sugar-cane industry. In New South Wales, the growing of beet-sugar had not been attempted, as the general opinion was that sugar could be produced more profitably from cane than from beet. The sugar-cane industry in New South Wales was founded at Port Macquarie in the very early days, and, though it extended considerably in the Northern District, it had latterly tended to recede. This was due to the discovery that Paspalum would thrive on the sugar-lands, and that the growing of this grass for dairying was more profitable than cane-growing. From the analyses of soils given by Mr. Easterby, he judged that in Queensland, as in New South Wales, sugar-cane was only grown on rich soils, and he could not suggest any crop that could take the place of sugar in Northern Queensland if conditions made cane-growing unprofitable.

Dr. S. S. Cameron, Director of Agriculture, Victoria, speaking by invitation of the Chairman, said that he hoped the Conference would not found any conclusions based upon what Mr. Easterby had said concerning the beet-sugar industry. He understood that Mr. Easterby thought that at present beet-growing should be confined to Maffra, on the ground that for defence and economic purposes the growing of sugar-cane in North Queensland was essential to Australia. He did not propose to discuss questions with a political bearing, but intended to confine his remarks to the industrial and commercial aspects of beet-growing. The industry at Maffra had had a most unfortunate history. The factory was established and staffed largely by Germans in 1893, and then, as now, the Germans seemed to have no idea of handling Australians successfully. After two years the company went into liquidation, and the Government, as the largest creditor, took possession of the factory. In 1911, the factory was reopened by the Government, and he admitted that until quite recently the results had been discouraging. Mr. Easterby had attributed this to two causes: (1) the climate, and (2) indifference of local farmers; but he contended that the second cause was directly dependent on the first. The factory was in a most unsuitable locality and situation, since beet required summer rainfall, and Maffra was in a dry region with winter rainfall. Whenever rain had fallen in the summer, however, the beet crop had been a success It must be remembered that the factory was financially handicapped by having to pay interest and depreciation on capital accumulated during past years, and hence it was only this year that an actual profit had been shown, though during the three previous years there had been a profit on the manufacturing operations themselves. This year the profit was £8,000—really, £9,500, since £1,500 had been spent on securing seed for next year's crop.

He maintained that beet-sugar growing was a natural auxiliary to dairy-farming in temperate climates, especially where condensed milks were manufactured. The refuse from the beet factory was a valuable stock food, whilst the sugar produced could be used in the condensed milk factories, and thus obviate the payment of large sums for freight on sugar brought from Queensland. He did not think the State should do more than establish one factory as an object lesson, but he thought if that proved a success other factories would spring up in different localities as a result of private enterprise. The cost of a factory turning out 4,000 tons of sugar, or treating a 40,000-ton beet crop, was from £60,000 to £100,000 in normal times; though at present it would be greater. The most economical plan was to keep the factory running till the whole crop for one season had been treated This meant running it for three months, or, under Australian conditions of climate, it might be from February to July. In that case, a factory regarded as a 40,000-ton factory could treat 50,000 or 60,000 or more tons.

The success achieved last year might, perhaps, be attributed to the higher price of sugar, £27 to £28, as against £20 in normal times, but, as against that, the price paid for beets had been increased from 20s. to 27s. 6d. a ton, and the cost of manufacture had also increased. Under Australian conditions he thought beet could be grown more cheaply in large areas, where its cultivation could be undertaken by mechanical means, rather than by peasant labour on small holdings, as was the practice in Europe.

The sugar content averaged from 16 to 17 per cent., but in dry seasons it was higher, even up to 27 per cent.; whilst in good seasons there was a larger yield with a lower sugar content. An extra 1s. per ton had been paid for every extra 1 per cent. over 15 per cent. when the 15 per cent. beet was being bought for 20s. per ton. In extraction there was a loss of from 3 to 4 per cent. of sugar. This year they averaged over 12 per cent.; that is, they got over 12 tons of sugar in the bags from every 100 tons of beet.

Prof. Paterson said that it was evident that the technical problems connected with sugar-growing were being very efficiently investigated in Queensland, and it did not seem necessary for the Commonwealth to take any action in this direction. The problems connected with sugar were mainly of a political and military character, with which the Conference was not called upon to deal. The present high duty on imported sugar had been imposed in order that sugar-growing in Queensland might be made profitable, and the reasons why it was desired to make it profitable were military and political. If, then, the development of the beet-sugar industry in the southern States rendered sugar-growing in Queensland unprofitable, the original reasons for imposing the duties on foreign sugar would cease to exist, and he thought it doubtful if the consumers would consent to the continuance of the high duties in the interest of Victorian beet-sugar growers. He would like more information as to whether sugar could be produced more cheaply from sugar-cane or from sugar-beet.

Mr. Easterby said that, under present conditions, he thought sugar could be produced more cheaply in Queensland than in Victoria. Dr. Cameron had evaded the main issue, which was that farmers in Victoria could grow other crops profitably, whilst in Queensland, if the sugar industry collapsed, they could grow no other crop profitably. In that case a vast territory would revert to jungle, and considerable towns all along the Queensland coast would disappear. The Commonwealth had appointed a Royal Commission, which spent a year making careful inquiries, and he had quoted their main conclusions in his paper.

Dr. Cameron said that the great development of the beet-sugar industry in recent years indicated that it was a cheaper source of sugar than sugar-cane. The cultivation of beets was of great advantage in enriching the land. Even if sugar could be produced as cheaply in Queensland as in Victoria, it would obviously be a great advantage to the condensed milk industry to have both milk and sugar produced in one district.

Mr. Easterby said that some years ago more sugar was produced from beets than from cane, but during the last eight or nine years the position had been reversed, and some millions of tons more sugar were now obtained from cane than from beets.

Prof. Perkins pointed out that beet-growing did not seem attractive. Dr. Cameron had said that the cost of production in Victoria was from £10 to £12 per acre, the average yield 8 tons per acre, and the price paid to the grower £1 per ton. Under these circumstances, he could not see where the profit came in. He thought that if beet-growing was a really profitable industry it would be impossible to hinder it; but that though Victoria had a perfect right to do so, it did not show a Federal spirit in encouraging an industry which was not very profitable and which was likely to damage an established industry in another State. He thought that a very strong case would have to be made out before he would be justified in recommending the expenditure of £100,000 for the establishment of a beet factory in South Australia; and when he found that after all these years only about 1,000 acres was under beet in Victoria, he did not think it was promising. He thought that it was inevitable that beet-growing would require more labour than most Australian farmers could give it, and it was more on a level with potato-growing than with the standard agricultural crops. Under these circumstances he thought the Queensland cane-sugar industry should not be interfered with, but rather should be encouraged.

CROPS FOR THE PRODUCTION OF POWER-ALCOHOL.

By W. Russell Grimwade, B.Sc.

National Importance of Reform.

It is perhaps unnecessary to emphasize before this Conference the importance that the matter of fuel for internal combustion engines has assumed in the past three years. In times of peace it was realized by a few that the internal combustion engine would cause almost a revolution in our ordinary peaceful and social existence, but even the most fanatical supporter of these types of engines could hardly have expected the confirmation that the demands of nations at war have created. Whereas it had only an industrial and social aspect before, it has now an extreme national and military importance. It is a very vague and indefinite line that distinguishes essential from non-essential industries, but no one can deny that an efficient prosecution of our primary industries and the elaborate systems of transport that now prevail are of paramount importance to the community in a struggle for its existence.

Military Significance.

The military organization which depends for the overland transport of its armies, arms, and commissariat chiefly on internal combustion engines, and which depends for its intelligence work on flying machines, which depend equally on internal combustion engines, is only one illustration of the dependence of our whole communal existence on the fuel that drives the piston.

It may or may not be that we have deposits of mineral oils in this country, but whether we have or not in no way minimizes the pressing necessity of developing our own potentialities and rendering ourselves independent in this most vital regard as soon as possible.

Importation.

Apart from the military aspect, there is an economic consideration urging the reform.

In 1915–16 the Commonwealth imported from overseas 17 million gallons of petrol, to the invoice value of £891,000. In 1916–17 the imports had risen to over 20 million gallons, of a value of £1,495,000. If to this figure be added the annual importation of 22 million gallons of kerosene, valued at £608,000, we have the sum of over £2,000,000 being sent to other countries in one year for our liquid fuel bill. The future has three possibilities—either the figure must increase, or our internal facilities must be restricted, or we must find another fuel.

This money is going out of the Commonwealth to foreigners. Even other parts of the Empire do not receive the bills we pay. With alcohol grown in our own lands the whole or greater part of this sum could be kept within Australia to distribute amongst our own people.

The Substitute for Petroleum.

Since the industrial developments that began to activate the world about a century ago, the natural resources and raw materials that the world has held in stock for us as raw material have been in a very large measure depleted at a greater rate than they bear interest. In no case has the capital been drawn upon so largely and been used so extravagantly as it has in the case of petroleum. Several examples may be found where, the world's capital having been used up, ingenious man has had to rely upon a system of production that operates according to the laws of supply and demand, and at the same time transfers the control from natural to human agencies. If it be postulated that a substitute must be found for the volatile fuels known by the generic name of "Petrol," then there is everything to indicate alcohol as the substitute. As industrial operations develop it may be replaced by a chemical of more complicated origin, but at present it is the accepted medium for the storage and convenient utilization of the sun's heat.

There are several diverse sources of alcohol already on the horizon of chemical activity, as instanced by the commercial manufacture of alcohol from inorganic sources. At the present time such a process is being carried on in Switzerland, and alcohol is being produced at a figure that enables it easily to compete with the more usual organic sources, but the process is dependent upon abundant supplies of cheap power, and Switzerland is a country which has "White" coal resources that are denied to Australia.

Sources of Alcohol.

The organic sources for the production of alcohol may be roughly divided into those of a cellulose nature, and the sugars and starches. So far the technical chemist has failed to make a success of the cellulose process, and although raw materials of this nature are generally fairly plentiful and cheap, it must be remembered that in a quantitive comparison with other countries Australia is poorly timbered. When we come to the sugars and starches we seem to come to Australia's opportunity. The three elemental substances that unite in the molecule of alcohol we have as abundantly as other countries, and do we not hold a special advantage in the broad acres and sunshine that are the "vital forces" necessary to group these atoms as we require them? In less flowery language, it would seem that Australia, far removed from the supplies of mineral oil, has special advantages over other countries for the cheap production of their substitute. The popular idea of cheap power-alcohol is that it shall be made from waste materials, but this is hardly confirmed by a close inquiry into the subject. The real reason why petrol is used as a fuel in preference to alcohol is the important one of price, but this preference is rapidly disappearing. Already petrol is more expensive bulk for bulk in Melbourne than alcohol, and the small difference that at present exists will be undoubtedly aggravated by an increase in the cost of petrol, and possibly by a decrease in the cost of alcohol when its production reaches systematic and large scale dimensions.

Waste Materials.

Present waste materials for the production of alcohol are molasses, wheat, and fruits. Of molasses, which are the ideal raw material for alcohol, there is really not a great deal. If all the molasses of Queensland were collected and converted into alcohol, it would only produce sufficient to replace the petrol requirements of that State, and the most common-sense way to regard the molasses question is that Queensland is specially favoured in producing its own supply of power-alcohol.

Waste wheat and wheat injured by mice and other causes is a possible source of alcohol, but cannot compete against other materials if a value of more than 2s. per bushel be credited to it, and the large quantities of waste wheat that exist in the Commonwealth at the present time can only be looked upon as adventitious.

Waste fruits are almost out of the question for the reason that their yield of alcohol is very low, their quantity does not reach a great tonnage, and their return to the grower when used for alcohol that has to compete against the mineral oils would not pay for the cost of collection.

The Production of Alcohol and Agriculture.

The trend of the generalizations set out above is to convince one that the solution of the whole problem of petrol substitution lies in a systematic and organized procedure for the production of fermentable matters, such as starch or sugar, and it is to seek advice and assistance of agricultural experts that the subject is introduced at this Conference. We are faced with the problem of providing a fermentable substance at such a cost that it will enable alcohol to be produced with profit to the distiller for less than the price of petrol. Petrol is now worth about 3s. 2d. per gallon in Melbourne, and, owing to the heavy freight charges, its value increases considerably at further distances from the chief shipping and distributing centres. Methylated spirit made from molasses sells in Melbourne at the present time from 2s. 3d. to 2s. 9d. per gallon. It is probable that the total Australian production is something less than 1,000,000 gallons annually. The freight charges of methylated spirits are very heavy from port to port of the Commonwealth, although not quite so great as those of petrol.

Price of Power-Alcohol.

It is exceedingly difficult to fix a value for power-alcohol, and it would seem as if it will be determined, for a time at any rate, by the value of petrol, Good authorities consider that the price of petrol will not fall much, if at all. below its present value. If that is so, the price of alcohol will be to the price of petrol as their relative consumptions in an internal combustion engine to do the same work. With engines that are not primarily designed for alcohol, but have been converted to use this fuel, the relative consumption of alcohol to petrol may be taken as 10 to 7. There is great probability that this ratio will be decreased as time goes on, and as engineers become familiarized with the use of alcohol. There are a number of minor advantages, such as safety from fire, smoother running, freedom from carbon deposit, miscibility with water, ease of lubrication, which largely discount the poorer showing that alcohol makes in comparison with petrol in consumption per brake horse-power; but dismissing all these indeterminable advantages, and taking the price of petrol in Australia to-day as being 3s. per gallon, the intrinsic value of power-alcohol is at least 2s. 1d. or 2s. 2d. per gallon.

The profit and trading expenses on methylated spirit at the present time are little guide to the same charges that should hold when alcohol is produced and traded in to the same extent as petrol now is.

The following table gives an idea of the value returnable to the primary producer for various crops which can be considered eligible for the production of power-alcohol :—

RETURNS FROM ALCOHOL CROPS.

Fixed Distillery Charges, Pence per gallon.		Price available for Material (pence).			Gallons yielded per unit.	Value of Crop.
		Alcohol at per gallon—				
		1s. 6d.	1s. 9d.	2s.		
					bushel (60 lbs.)	s. d.
Wheat	.. 4·5	13·5	..	..	..	2 6 per bushel
		..	16·5	..	2·2	3 0 ,,
		..	..	19·5	..	3 7 ,,
					bushel. (50 lbs.	
Barley	.. 4·5	13·5	..	..	..	1 8 ,,
		..	16·5	..	1·5	2 1 ,,
		..	..	19·5	..	2 5 ,,
					bushel (56 lbs.)	
Maize	.. 5·0	13	..	..	..	2 2 ,,
		..	16	..	2·1	2 10 ,,
		..	..	19	..	3 4 ,,
					Ton	
Potatoes	.. 5·5	12·5	..	..	22	22 6 per ton
		..	15·5	..	..	28 6 ,,
		..	..	18·5	..	34 0 ,,
Beet..	.. 5·5	12·5	..	..	..	14 6 ,,
		..	15·5	..	14	18 0 ,,
		..	..	18·5	..	21 6 ,,
Sorghum	.. 6·0	12	..	..	..	12 6 ,,
		..	15	..	12·5	15 6 ,,
		..	..	18	..	19 0 ,,

Systematic Decentralizing Scheme.

The uses of alcohol are such that its demands are very evenly distributed over the country in proportion to the population. In order to make for the greatest efficiency and economy it is essential that any scheme for the production of cheap alcohol must be established on a decentralizing basis. Working with the ideal of producing the alcohol in those areas where it is to be used, this not only saves the heavy charges of freight, but also economizes on the charges of packages and containers. These ideals are permissible with alcohol for the reason that, more generally than with chemical factories, the cost of the plant and supervision and overhead charges are more nearly proportional to the output than in factories concerned with more involved operations. The farmer who has to produce the material for the manufacture of alcohol must be able to do as well or better with his new crops as he does with the old, and in fact any scheme for the production of this or any other material that demands for its successful establishment financial concessions from any class of the community is foredoomed to failure.

Eligible Raw Materials.

The following table gives figures relating to the most attractive raw materials of an agricultural nature for the production of alcohol :—

Crop.	Average Yield per acre for Victoria.		Present Price.		Yield of Alcohol per ton in Practice.	Yield of Alcohol (95 %) per acre.	Efficiency of Process.	Cost of materials per gallon.
	Bushels.	Tons.	Per bushel.	Per ton.	Imp. gallons.	Imp. gallons.		Pence.
			s. d.	£ s. d.				
Wheat	12·5	·33	4 9	8 17 4	80–85	27	..	26
Barley	19	·42	3 0	6 15 0	65–70	28	..	24
Maize	48	1·2	3 3	6 10 0	80–83	97	80%	19·2
Potatoes	..	4·0	..	4 0 0	20–24	88	70%	43
Sugar beet	..	10·0	..	1 7 6	12–16	140	65%	23·6
Sorghum	..	18–20	..	1 0 0	12·5	230	65%	19·2

Sorghum is ruled off from the others, for the reason that there is some uncertainty as to its yield ; but you will note that it and maize are by far the most attractive materials to investigate. Crops with such a low yield of alcohol per ton as potatoes are difficult to consider as successful for our purpose, and it is only where they have such an extraordinarily high yield per acre as in the case of sorghum that they become interesting. With a very low yield per ton or per acre in which much inert matter has to be handled the process can never become one of high efficiency.

It is difficult for one ignorant of the science of agriculture to indicate to a group of experts the lines upon which to proceed, but the following features seem to be demanded from a commercial and business-like consideration :—

The crops should have a fairly reliable prospect in the range of climates to which our States are subject. It is, of course, probable that different crops will be better adapted to different localities. The efficiency of harvesting machinery is highly important. With most of the cereals at the present time the implements for the handling of the crop have been brought to a very high state of efficiency, but unless there is a reasonable prospect of similar efficiency in machinery for handling an alcohol crop it is a very serious obstacle in the path of success. The harvesting of maize is a more difficult operation for the mechanical engineer than the harvesting of wheat or barley, and this is a decided disability to maize, which otherwise is so attractive. The harvesting of potatoes is also difficult.

Harvesting.

A fundamental scientific consideration in the establishment of this business is the need for returning to the soil such elements as are not required in the final product.

The phosphates and nitrogen that are so essential to the metabolism of the growing plant and which in the case of food starch ultimately serve as human food need not in the case of alcohol be removed from the locality in which they do their work. The successful development of potatoes as sources of alcohol in Germany seems to have depended very largely on this fact.

The phosphate, potassium, and nitrogen are all returned to the soil, and are not removed from the cycle of operations. These substances which we may regard as " catalysts " remain in the distillery mash, and the form that this product of the distilleries takes is specially important. If it is capable of being used directly as a fertilizer for a fresh crop, that is the simplest process. If it is not so capable, it may be necessary to recover these catalytic materials by the medium of stock ; and here the value of the distillation slops as a stock or cattle food has a distinct bearing on the establishment of the scheme. One essential feature arising from this consideration is that of working the crops in local centres not too far removed from the growing areas.

This aspect is favored by the fact that the use of alcohol for internal combustion engines will most probably be introduced through the type of engine in general use for farm purposes. The stationary slow-speed engine used for pumping, chaff-cutting, and general farm purposes is the type that can be converted most readily to burn alcohol.

Ideal Conditions.

The ideal conditions which we must picture are the farmer tilling the land, sowing the crop, harvesting, and transporting his raw material to the local distillery with spirit produced from his crop. He receives in return for his crop not only a cheque, but a further supply of alcohol to work his machines for subsequent operations, and a pig or cattle feed for the fattening of his stock and the regeneration of his land.

Choice of Crop.

Which crop is the one to be developed for this purpose is a point which must be left to agriculturists, and in deciding it they must be guided not only by the considerations affecting every growing crop, but also those social and economic aspects which are peculiar to this business. With the range of climate and soil conditions that the Commonwealth enjoys it is most unlikely that a universal material can be recommended for the purpose in view. Queensland, with its tropical and sub-tropical climate, may find sugar cane the most suitable, whereas Victoria may have to rely upon maize. The American authorities seem to attach most importance to sorghum, and from the figures they quote it seems remarkably promising. Whether the range of climate of our southern States is suitable, and whether the farmer can do as well out of it as he can out of his existing crops is a matter that agriculturists can decide better than a chemist ; but one point of chemistry needs emphasis.

Sugars and Starches.

From a distiller's point of view, sugars are preferable to starches. Starches have to be converted by a chemical process into sugars before they are capable of fermentation, and this added operation with its necessary re-agents is an added expense inherent to starches. The conversion of starches to sugars for the fermentation of power-alcohol should be a much cheaper matter than now obtains in the production of potable spirit. Whisky distillers are compelled by law to bring about the conversion with enzymes, which are expensive, difficult to handle, and comparatively inefficient. The conversion can be brought about much more cheaply by mineral acid.

Sorghum would seem to produce cane sugars so cheaply that it may be wondered why it is not utilized for the commercial manufacture of sugar. One reason is that the 12 per cent. of carbohydrates in its expressed juice is contaminated with gums and extracts which exert a peculiarly inhibiting effect on crystallization.

Uncultivated Materials.

The popular mind is, fortunately, being turned to the importance of producing a cheap liquid fuel. One result of this is that many strange materials have been suggested as a source of alcohol, and a favorite one is waste materials and starches of uncultivated origin. Upon inquiry, it is invariably found that alcohol produced from waste materials (excepting molasses) would be far more expensive than that produced from regular supplies at food prices. In general, it may be stated that processes based upon raw materials of a sporadic and adventitious nature cannot compete with those produced in an organized system of permanent rotation.

In conclusion, it might be as well to give you a very brief account of the work that has been carried out by the Special Committee appointed by the Advisory Council of Science and Industry to inquire into this matter. It was found that the subject consisted of three distinct problems ; the problem of the engine, the problem of the supply of the alcohol, and the problem of denaturation. At first it was thought that the engine would be the chief difficulty, but this has not proved to be the case. Denaturation is not a difficult problem, but is an artificial barrier which may be removed by legislation. The problem which concerns this Conference is the supply of alcohol, and it is this aspect that I have set before you.

The table showing the returns from alcohol crops perhaps requires some explanation. The first column contains the fixed distillery charges which obtain at the present time. They have been reduced a little, but they are based upon practical experience, and are the result of inquiry among manufacturers.

The reason why sorghum was placed highest was, I think, that it was unknown, and manufacturers wish to protect themselves. That can be the only explanation, because the fermentable material in sorghum is chiefly cane sugar. If we take the limiting value of power alcohol at 2s. a gallon, which is the value set upon alcohol from its proportionate value to petrol, the farmer should be able to get 19s. per ton for his sorghum, and the other figures correspond in the same way. It is for you, gentlemen, to decide which of these returns are the most promising, and whether they would pay the farmer.

Discussion of Mr. Grimwade's Paper.

Mr. Breakwell asked if information was available as to the production of alcohol from grain sorghum. This had been very successful at Yanco, yielding 120 bushels per acre.

Mr. Grimwade said that, according to the information they had received, grain sorghum contained a higher percentage of fermentable material than any other cereal. He pointed out that a green crop had an advantage over a grain crop, in that it was not liable to destruction by fire.

Mr. Easterby asked whether the fuel called natalite had been considered. This was a mixture of alcohol and ether, and was said to be worth about 2s. per gallon. The Queensland Government investigated the possibility of producing it from waste molasses, but found that the cost of production would be more than 2s. per gallon.

Mr. Grimwade said that natalite was an excellent fuel, and could be used immediately in a petrol engine, without necessitating any alteration of the engine. It, however, involved a source of alcohol just as much as alcohol itself, since the 40 per cent. of ether it contained was manufactured from alcohol, and this meant an extra chemical process. It probably did not offer the great advantage that alcohol possessed over petrol, in that the thermal efficiency of alcohol was 40 per cent. and that of petrol less than 30 per cent. Moreover, another material advantage of alcohol over petrol was its freedom from fire and low volatility, which would lead to a saving of insurance expenses. In these respects natalite was under the same disabilities as petrol.

Prof. Paterson asked whether the prices shown in the table were calculated from theoretical considerations after the analysis of the materials.

Mr. Grimwade said that in every case except sorghum they were based on actual factory experiments on a large scale. In no case had the amount of alcohol produced exceeded 80 per cent. of what was theoretically possible, and he thought that the efficiency of a process like fermentation should be much greater than 80 per cent. Hence there was every prospect that the actual prices that could be offered to growers might be higher than those in the table.

The figures for sorghum had been obtained from reliable American sources, since very little is grown in Australia and none distilled. He thought it would be possible to carry out tests on the Australian material if it was thought desirable.

He pointed out that the crops which he had referred to had simply been selected because, in his opinion, they were the most promising, but this was only a matter of opinion. He had already given his reasons for disregarding waste materials. The last column in the table gave the price that the distiller should be able to pay the grower.

Dr. Cameron pointed out that the amount of water present in green sorghum was very variable, and farmers might make fortunes if they sold material containing a high percentage of moisture at 19s. per ton. With reference to sugar-beet, he mentioned that the price of £1 7s. 6d. was that for topped clean beet. The part of the beet which was removed for this purpose was from 15 to 25 per cent. of the weight. It was removed, because it contained matters which interfered with the extraction of sugar, but it contained a certain amount of sugar, and for the purposes of fermentation it could be included. An additional 20 per cent. of material might make beet look as promising as sorghum.

Mr. Grimwade said that the manufacturer would only pay 19s. for sorghum if he could get 12·5 per cent. of alcohol from it. If the sorghum contained much moisture the price would be less.

Mr. Quodling said that grain sorghums in Queensland had given good yields under conditions where maize had been a failure. The yields were usually about 60 to 80 bushels per acre, but last year they had obtained yields up to 103 bushels. The Queensland Department of Agriculture would be pleased to provide either grain or green sorghum for the purpose of having them tested for alcohol yield.

Prof. Perkins suggested that pumpkins or melons, which produced huge crops, might be suitable for the production of industrial alcohol.

Mr. Grimwade said that water-melons yielded 2 to 3 gallons of alcohol per ton, artichokes 23 gallons, bananas 13 gallons, and grass-trees 12 gallons.

Prof. Watt suggested that the figures given for sorghum very possibly referred to the sorghum used in America for the production of sugar. The sorghum grown in Australia was very probably different, as there were very many varieties of sorghum. He thought that grain had a great advantage over a green crop, in that it had a constant composition, whereas green sorghum would vary much in sugar content, according to its stage of growth and the climatic conditions. He thought that maize should not lightly be dismissed from consideration, since 3s. 4d. a bushel was very nearly a payable proposition, and the area under maize could be very largely increased in Queensland, New South Wales, and Victoria.

There could be no question that sweet potatoes would give a better yield than ordinary potatoes.

Mr. Pye said that the area in which sorghum could be grown was much more extensive than that suited for maize, since it was much more hardy. Among the large number of varieties of sorghum, the highest in sugar content should be selected, or seed obtained from America.

Mr. Sutton also stressed the much greater hardiness of sorghum than of maize, and pointed out that while hot winds were destructive to the latter, their chief effect on sorghum was to increase its sugar content.

Mr. McAlpine pointed out that Japanese millet was also much more hardy than maize.

Mr. Grimwade said that he had not considered any form of millet. Whilst green crops had an advantage owing to there being no danger from fire, grain crops had the great advantage that they could be stored. The prices he had quoted were city prices, but if distilleries were established in country places they would be able to deliver the produce much more cheaply. It would require three times the amount of maize at present grown in Australia to produce sufficient fuel for the internal combustion engines of the Commonwealth.

Mr. Wenholz referred to the figures given for maize. Whilst 3s. 3d. might be the price current in Victoria, in Sydney the price had been fixed at 4s. 6d. In New South Wales it cost from 2s. 6d. to 3s. a bushel to produce maize, and when the price fell below 4s. the farmers would not sell it, but preferred to feed it to stock. Under these circumstances, 3s. 4d. would be no inducement to them to grow maize, but if the price of alcohol rose above 2s. they might see a greatly increased production of maize. At present lands suitable for maize-growing along the coast were largely given up to dairying, but if maize became more profitable a great increase in the area of maize might be effected.

Dr. Green pointed out that the extraction of sugar from beets was a complicated process, but that fermentation was considerably simpler, besides which a lot of material such as molasses, now largely wasted, could be utilized for fermentation. The utilization of cellulose for alcohol production was worthy of consideration. Though the process of making alcohol from sawdust had not been a success in America, it was possible that such materials as pumpkins and mangels, which contained both sugar and cellulose, might be successfully used.

SIXTH SESSION, 16th NOVEMBER, 1917.

SOME SUGGESTIONS AS TO THE COMMONWEALTH ENDOWMENT OF AGRICULTURAL RESEARCH.

By Arthur J. Perkins, Director of Agriculture in South Australia.

I have been asked to introduce to you the subject-matter of Agricultural Research Work, with which for many years I happen to have been connected in some small way. Beyond this simple request which I appreciate, I have been given no definite clue as to what is expected of me ; nor can I feel certain of the particular direction our discussions are likely to take. If, however, the end in view is to discover in the assumed interests of agricultural progress how to manacle research most securely, then it is possible that neither by temperament nor convictions am I qualified to show the way. Honesty, therefore, compels the early admission that if it is to be our purpose to devise how agricultural research can best be captured, harnessed, and brought under close control of centralized superior authority, I must offer to these plans such opposition as I am capable of. Not that an ideal of this kind is in theory unattainable. If we were dealing with mechanical automata, and not with flesh and blood ; with a geometric progression and not with agricultural research, it is even conceivable that some such scheme might be in the very best interests of the Commonwealth. In the world that we know of, however, it can but lead to much perfunctory spilling of ink, much interdepartmental correspondence, sheaves of regulations, but of real live work I see no prospect whatever.

Perhaps I should give some illustrations of the ubiquitous stumbling blocks that unavoidably hamper progress in most centralized systems. When I was in Egypt in 1910, the Principal of the Ghizeh Agricultural College told me that, on appointment, he had been informed by the British Resident-General that agricultural research work was one of the sacred functions of the Secretary of the Khedival Agricultural Society, upon which he would trench at his peril. But it is not necessary to go so far from home for apt illustration. I understand that in one of our States, some few years back, official instructions were issued to the effect that no agricultural research work was to be undertaken in that State without the sanction and approval of a central committee of three sitting in the metropolis. We have here ingenious devices to control captive research and to keep it on the narrow straight way ; in one sense they would probably be effective, since by killing individual initiative they would do away with all incentive to research. Organization, subordination, symmetrical official hierarchy in which work and responsibility are passed on from grade to grade may serve their purposes in some cases. But in what concerns us to-day, if the time of the man at the apex is congenially absorbed in warning off subordinates from his particular harvest, whilst these same subordinates can see nothing more profitable than the line of least resistance and dead men's shoes, what prospects can there be of results essentially dependent on individual inspiration and effort? If—and I apologize in advance for unavoidable personal reference—at any time I have succeeded in some slight attempts at research work, it is because I have always fought for a free hand, and in the end have been allowed it.

Hence, by way of preliminary, but foundation, observation I shall suggest to you that, notwithstanding extraneous financial assistance, if agricultural research work is to flourish in our midst, one of the primary essentials is that it shall be free.

Now, I do not wish to dispute the relativity of things, and admit that freedom is not necessarily anarchy. Hence, if the principle of individual freedom of inspiration and action be conceded, it can be admitted without difficulty that research, which, unaided, can make but poor progress, must in return for solid support agree to conform to the normal obligations of gratitude. In other words, whilst I do not believe that research, essentially a matter of personal inspiration, can be to any advantage harnessed and driven, it can always, if adequately catered for, be coaxed into fruitful lines of effort. Capacity for research, on the other hand, although not a common growth, is probably of more frequent occurrence than is usually suspected; the medium, unfortunately, in which it is compelled to live and have its being is very rarely congenial, and frequently fatal; hence it is to this aspect of the question that I propose chiefly addressing myself.

Apart from any other consideration, the first requisite would appear to be the discovery of adequate human material. Clearly we can have no research work without competent research workers. And in the absence of any earlier organized effort in this direction, we must look to the rising generation to supply our present needs. Hence the prime necessity, not only of fostering a love of research in young students, with good natural aptitude, but, in addition, of placing within their reach the means of taking up any line of work which happened to appeal to them. And, whilst I should be prepared to welcome research workers from any point of the compass, I incline to the belief that in the matter of agricultural research, it is upon agricultural students chiefly that we shall have to depend.

I should, perhaps, state here that, in championing the cause of agricultural students, I am very far from oblivious of the claims of others. Agriculturists generally would, I believe, be the first to acknowledge their great indebtedness to the various science adepts who have, in modern times, helped to lay bare to them the mysteries of an hereditary art; but who is there that does not know that much precious time has been wasted, and much good work has failed of its object, chiefly because of the lack of a little early agricultural training? In the matter of agricultural research, I know of no more fruitful individual work than that of Lawes and Gilbert; and its saneness must be attributed in the main to the sound farming knowledge of Sir John Bennett Lawes. Hence I am persuaded that, whatever their ultimate scientific bias may happen to be, those called upon to carry out agricultural research in any of its branches should at all times be able to look back upon sound agricultural training. I suggest to you, therefore, that our agricultural colleges should be looked upon as the nurseries from which future agricultural research workers are to be culled. In furtherance of this object, the transplanting from these colleges to the Universities should be made easy and inviting for those showing any degree of research aptitude. And by way of a first recommendation bearing on the subject, I suggest the establishment at all our agricultural colleges of special exit research scholarships, enabling the specially gifted to pass on to the broader science training of the Universities. The responsibility for awarding these scholarships should be shared jointly by the college authorities and the University concerned.

Admission to the University under one of these scholarships should not tie down successful candidates to too narrow a course of study. Agriculture is essentially many-sided, and can draw occasional inspiration from any of the sciences. Hence it will suffice if it be stipulated that research scholars occupy their time at the University adequately among the sciences, pure or applied, with the addition of agricultural economics for special cases.

We look to the Universities for the decisive touch in the training of these future research workers. Some, no doubt, and for one reason or another, will drop out of the race; a sufficiency, it is to be hoped, will from time to time swell the ranks of potential research workers. Unless, however, mere waste of money is contemplated, it would be folly that assistance to research should cease with the professional training of the worker.

We shall have to see to it that, his training completed, he will find ready to hand an appropriate medium in which to demonstrate the value of his training. Hence it seems to me that the Universities, which in Australia have not hesitated to recognise in agriculture a respectable branch of training, should be provided with facilities for establishing in their midst Agricultural Research Stations.

If, as will probably be agreed, we cannot have research workers without some sort of Central Research Station, the association of the latter with the Universities would appear to me singularly appropriate. I submit a few points which appear to support this view. In the first place, there is nothing to be gained in multiplying indefinitely Research Stations, the adequate equipment and upkeep of which are always unavoidably costly. The Universities are the natural training grounds for research workers in all branches of human activity; hence, apart from any other consideration, they must be supplied with adequate scientific equipment. The addition of a definite Research Station would be therefore but a natural expansion of their normal functions, and would help much towards vitalizing the ordinary training imparted within their walls. Moreover, it would clearly obviate some degree of unavoidable duplication and overlapping. Further, the Universities can offer the great advantage of close association with kindred minds occupied in analogous tasks. And, finally, the general atmosphere of the Universities is such as to offer solid guarantees for the character of the work undertaken within their precincts.

Hence I suggest that the Australian Universities, or, at all events, those adapted to the purpose, be enabled to found Agricultural Research Stations. In this connexion I may, perhaps, be allowed to speak on behalf of the University of Adelaide, with which I happen to be officially connected. This University, through the generosity of a local resident, Mr. Peter Waite, already stands pledged to an Agricultural Research Station. We have been placed in possession of a large area of land admirably situated for the purpose within the suburban area of Adelaide. What we lack at present, however, is adequate funds to give effect to our day dreams. And possibly some of the sister Universities may be similarly situated.

I shall assume, therefore, that you will agree that responsibility for training carries with it responsibility for future work, which can best be met by the creation of University Research Stations. And if for this purpose financial assistance is not available from ordinary sources, there is from the national view-point no more promising opening for Commonwealth subsidies. To these well-equipped stations should be attached bursaries or fellowships—call them what you will—carrying with them reasonable emoluments for post-graduate students willing and able to carry out agricultural research in any of its many branches. It should, too, be made imperative upon the Stations to issue periodical accounts of all work carried out under their auspices. Apart from the fact that in the public eye it will loom as evidence of something done in return for money spent, compulsory publicity will establish a wholesome check on hasty generalizations and immature work generally; and forge between kindred institutions an ever-present bond and means of communication, which will do much towards obviating the supposed evils of overlapping.

I cannot leave these Research Stations without a parting observation which may perhaps be attributed to professional bias. I would urge that the leadership of an Agricultural Research Station should be in the hands of a fully-qualified agriculturist. From my limited horizon this stipulation appears so self-evidently essential to success that reference to it seems almost superfluous. Nevertheless, observation has taught me that this is not necessarily the case, and I have sometimes been forced to the conclusion that practical acquaintance with agriculture is at times one of the last essentials in admittedly agricultural appointments. In the main, results secured at an agricultural institution must ultimately be interpreted in terms of agricultural values, and towards them, much to the prejudice of work done, it must be clear that neither inspiration nor leadership can come from one who is not competent to weigh the professional issues involved. Moreover, it must surely be humiliating in the extreme to the nominal leader if for details of practical import he must at all times depend on the judgment of those in relatively subordinate positions. In this connexion, therefore, I shall content myself with the remark that from my biassed view-point, if material assistance is to be given to the Universities towards building up Agricultural Research Stations, it should be a binding condition upon them that the leadership of these Stations be placed in the hands of men who, whatever their other qualifications, have undoubted first-hand knowledge of Australian agricultural practice and conditions.

The nature of the work undertaken at the University Agricultural Research Station would be limited only by the means available for the purpose and by the special qualifications of those at the time attached to it. Time does not permit that I should enter into details on the subject, nor in the circumstances is it necessary. In summary, every fact and feature, closely or remotely connected with the pastoral and agricultural industries (using these terms in their most comprehensive meaning) would be open to investigation at the Station. And under skilful guidance we may take it for granted that, apart from routine work, and work which individual idiosyncrasies will seek out, questions of the day or of present moment would receive careful consideration.

There is one type of difficulty which it appears to me these Research Stations could meet with ease. Personally, I have frequently been confronted with important local problems which could not be solved satisfactorily from the meagre data supplied by untrained local residents. Very frequently, much to the advantage of the districts concerned, difficulties of this kind could be dealt with were it possible to place in temporary residence in the affected district à competent observer in charge of investigation work. Unfortunately, Departments of Agriculture—or, at all events, such is the case in the one over which I have the honour to preside—are not as a rule sufficiently well staffed to be able to detach men from routine work for purposes of this kind, and the problem must often be left unsolved, much to the loss of the locality concerned. Hence I suggest that the University Station should be in a position, when asked to do so, to lend special research workers, to whom the study of special local difficulties could be assigned, and who would, for the time being, devote the whole of their time to these investigations. I am satisfied that in this direction alone much valuable work could be done which would do much towards justifying any expenditure in building up these Stations.

Hitherto I have dealt exclusively with what might be termed official research; but I am very far from thinking that this is the only form of research worthy of consideration or assistance. I am aware that it is the time-honoured custom of officialdom to look askance at freelances; personally, however, I have never been able to share this feeling; nor could I agree to countenance it in a thing so essentially dependent on individual inspiration as research. I make the additional suggestion, therefore, that financial assistance be offered to any promising extra-official attempt at genuine agricultural investigation work. Clearly, however, such assistance could not be given except on the favorable report of those qualified to judge of the value of the investigation and of the competence of the investigator. Hence, with suitable precautions against the possible bias of interested parties, provision should be made for the impartial examination of any claims that may be put forward under this heading.

Need I, in conclusion, extend on the value to the States and the Commonwealth of systematic and many-sided agricultural research? It seems hardly necessary. We are in every sense countries new to agricultural experience; we are feeling our way as we go. In the matter of underlying principles we are more or less wholly dependent on investigations carried out elsewhere, and under conditions often very dissimilar from our own. Hence, apart from the few lines of work which, among many difficulties, our local Departments of Agriculture have in the past been able to give effect to, almost everything remains to be done towards the creation of a sound theoretical basis upon which our agricultural practice can be built up, and, whenever necessary, made to vary with the fluctuations of economic conditions. We need to check even the agricultural axioms of other countries; nor, as was unavoidable elsewhere in older times, can we afford to leave the enunciation of our own to chance and the painful struggles of many generations.

It may, perhaps, be urged that hitherto we appear to have made good progress without the aid of research, and that there is no reason to assume that we shall not continue doing so in the future. Let us not forget, however, that our initial successes have been easily secured on extensive farming ventures, which always lack the nicety and precision of more intensive operations which we can no longer avoid. I am of the opinion, which is, I believe, shared by many, that throughout Australia agriculture, if it is to continue a profitable national undertaking, must learn to set aside many of its hasty and spendthrift ways, and aim steadily and continuously at higher gross returns. This feature alone opens up a vast field for useful investigation work, in which adequately equipped Research Stations should take no mean part. And, in view of the early onrush for the land of disbanded soldiers both from Australia and other British territories, it may be added that early action in this direction is essential to the future welfare of Commonwealth and States alike.

Finally, I shall summarize the various suggestions I have made and endeavoured to justify :—

1. Official financial assistance notwithstanding, effective research must be free research.
2. Exit Research Scholarships opening the way to the Universities should be established at all our Agricultural Colleges.
3. University Research Scholars should devote their time unhampered to the sciences, and, if inclined thereto, to agricultural economics.
4. Financial assistance should be given to one or more Universities for the complete equipment and maintenance of one or more Agricultural Research Stations.
5. Post-graduate bursaries or fellowships should be established at the University Research Stations.
6. University Research Workers should be available to the Departments of Agriculture whenever special questions calling for close expert investigation arise.
7. Financial assistance should be offered towards any approved investigation work by competent private persons.

AGRICULTURAL RESEARCH AND THE PREVENTION OF OVERLAPPING.

By R. D. Watt, M.A., B.Sc., Professor of Agriculture in the University of Sydney.

I feel that I owe the Conference an apology for not having prepared a set paper, the reason being that I understood that I was expected to summarize the general conclusions of the Conference, with a view to the proposing of resolutions. I think we have wisely passed resolutions in connexion with each subject when it was discussed, but that procedure has rather taken the ground from under my feet. The subject of agricultural research, however, is so immense and so important that there should be no difficulty in making some remarks upon it.

I take an even wider view of agricultural research than our Chairman, and, when I speak of it to-day, I wish you to understand that any experiment however simple carried out in the field or laboratory to acquire definite information regarding any agricultural or pastoral problem comes under the heading of agricultural research.

Taking that view, as I have indicated, the subject is very vast and comprehensive; in fact so vast that it reminds me of a subject advertised by a young clergyman, for which he was reprimanded by his former professor. The subject advertised for a short address was "The Past, Present, and Future of God and Man." The comment of the professor was "Why leave the Devil out?" The first point I wish to impress upon you then is the *vastness* of the subject, a point which will perhaps be more obvious as we proceed.

Then I do not need to impress upon a gathering such as this the *importance* of agricultural research. In glorifying agricultural research, I do not wish for a moment to belittle other branches of applied science, such as science applied to medicine or applied to engineering. Still less would I desire to belittle the value of research in pure science, especially because I fear that, in a young country like this, we are apt to overlook its value and to place most importance upon what might be called the utilitarian side of science. But many examples could be given, if time permitted, to show how agricultural science and agricultural research have progressed as the direct result of some discovery in some pure science, such as botany or chemistry. And in glorifying agricultural research I should be the last to belittle the value of agricultural education, which is so closely linked with it.

There are many reasons why agricultural research should form a prominent feature of the activities of the Commonwealth of Australia. Its ultimate aim is to increase the productivity of the country, and it would be impossible to exaggerate the importance of that at the present juncture; for, when the war clouds have passed away, when men have beaten their tanks into tractors and their bayonets into binder-blades (to modernize a scriptural quotation), and peace once more comes to this troubled world, there will be a huge bill to pay, and that bill can only be paid as the result of increased—and greatly increased—production.

Prof. Perkins has alluded to the fact that agricultural research is necessary in Australia for a particular reason. I should say that agricultural research is essential here for more than one reason, and I am perfectly sure that our Chairman will agree with me; in fact, nothing that I am going to say will contradict anything he has said in that respect. The first reason is that our sense of honour bids us carry out research here for the same reason that we have sent our soldiers to the front. We should not depend upon the expense incurred and energies expended on agricultural research in other countries whilst we sit back and utilize the results. But the other reason is even stronger, and it is the reason Prof. Perkins has mentioned, viz., that we cannot, in the majority of cases, directly apply the research that is carried out in other countries to Australian conditions.

Now, with regard to the *subjects* of research, as you will readily imagine, this is a huge subject. In elementary text-books in agriculture, we are told that there are three factors in production—the soil, the plant, and the animal. That, however, does not complete the list, because the plant depends as much, or almost as much, on the atmosphere as it does on the soil ; but I would not recommend the advisability of carrying out research work with a view to modifying the composition of the atmosphere in order to increase the production of our farms ; and I am not sure I would recommend strongly to this Conference the carrying out of experiments designed to increase the rainfall of this country however desirable the result would be if attained. Agricultural research must be chiefly directed towards the improvement of the conditions connected with these three main factors—the soil, the plant, and the animal.

Firstly, *the soil*. Additional research is needed in Australia into the physical prope ties of our various soil types, with a view to their possible modification and control by ordinary farming methods, by the use of cultivation implements, by the rotation of crops, and so forth. Much more research is also needed into the chemical character of our chief soil types, and this in itself is a huge field. In connexion with that the devising of a better measure of the manurial requirements of soils than any method at present in existence is of importance. I think no one who has great experience of soil analysis in connexion with manurial and other experiments is at all satisfied with the value of the laboratory work, and, although a great amount of research has been carried out in other countries into this important question, chemists, I think, will freely admit that the matter is in an unsatisfactory position at the present moment.

Then a great deal of attention has been directed recently to the biological character of the soil, and a vast amount of research still remains to be carried out before we can get a true picture of the myriad organisms of the soil, and the exact part they play in the making available of the plants' food material. Here our conditions are so different from those in other parts of the world that research along these lines would be particularly valuable. Before I leave the question of the soil, I should like to say that it seems to me that the time has arrived when we should make a start with a problem which will take many, many years, perhaps even centuries, to complete, namely, the making of a soil survey of the Continent. The undertaking is so large and far-reaching in its possible results that it is eminently desirable that a beginning should be made at once. A soil survey by itself would, however, be of comparatively little value under Australian conditions, and the term would have to be used in a very wide sense so as to include a climatic survey and a statistical survey. If a true soil survey were combined with these two, much valuable information could be obtained, and much of the research that is carried out in one State or district could be applied to other States and districts where the conditions are approximately similar. The first step towards such a soil survey, of course, would be the collection and the co-ordination and publishing of the facts that are already in existence. There is an immense amount of information largely hidden away in reports and maps and so forth in the various capital cities of the Commonwealth from which, with a good deal of hard and painstaking work, data could be got which would prove the starting point and nucleus of a systematic soil survey.

I shall now take the subjects a little bit out of their natural order, and deal next with the *animal*. The animal is one of the most important factors in agricultural production in its widest sense, and here the new views and the new theories with regard to heredity are, I think, going to help us considerably, and I think that Australia ought to play her part in the carrying out of systematic breeding experiments. The larger animals of the farm, more particularly the horse, do not offer a very good field for such experiments, and I feel certain that the breed of horses could be more rapidly improved by the methods adopted by most of the Agricultural Departments—by the registration of the suitable and sound stallions, and also by encouraging the importation by the Departments themselves or by private individuals of the best types of farm horses from the countries in which they are bred. But there is one feature which the new views of heredity emphasize, namely, that a stallion or a sire of any kind should be valued not so much because of its ancestors as because of its progeny, because if there is one thing that Mendelism teaches, it is this : Look to the progeny of an individual rather than to its ancestry if you wish to know its real value.

Cattle, especially dairy cattle, offer a more promising field for investigation, because we can accurately measure the most important feature about a dairy cow, namely, the amount of milk or the amount of butter fat she can produce, and the new views of heredity throw a good deal of light on the inheritance of these characters. The new views emphasize what was vaguely appreciated before, that it is extremely important to have a bull derived from a good milking strain at the head of the herd. The experiments carried out in Denmark along these lines are extremely instructive, and should encourage us, wherever possible, to persevere with our herd-testing and similar work.

Coming now to the smaller stock of the farm, the principles of heredity initiated by Mendel and others, and derived from an elaboration of their work, again help us considerably. It seems to me remarkable that so little accurate high-class scientific work, has been done with regard to the character of what is, after all, our chief product, namely, wool. Practical men, working along lines that are really scientific, have achieved remarkable results—results that have done credit to the Australian pastoralist, but it seems to me that a still further advance could be made if a further, a deeper, research were carried out into the factors that influence the market value of wool, and the mode of their inheritance.

With regard to poultry, there is no doubt about the fact that a recent development of the Mendelian theory has led to a result that is likely to be of the greatest practical importance, particularly in connexion with our Repatriation Scheme, because there are few land occupations that are so suited to a disabled soldier as the rearing of poultry. The instance that I wish to quote is this—that in carrying out breeding experiments with poultry, an interesting case of gametic coupling has been discovered the practical result of which is that, whilst in the breeding of cattle for the production of milk and butter the results depend on both the sire and the dam, the breeding of an egg-laying strain of hens depends entirely on the male, because there is this feature of gametic coupling, namely, association of the Mendelian character of femaleness with the Mendelian character of low productivity. To give an illustration, Dr. Raymond Pearl, in America, for a period of ten years carried out experiments in connexion with the breeding of poultry for egg-production, and it was found that if he took a male bird from a good laying strain and mated that bird with what had proved in previous years to be hens of high production, and mated that same bird with hens of low production, there was no difference in the progeny of those as far as egg-production was concerned. This is interesting, if it can be confirmed, and it seems to have received a great deal of confirmation already. This one instance surely shows how research work on the laws of heredity may become of great practical value.

Research work in connexion with the soil is important. Research work in connexion with the animal is important, but both of these sink into relative insignificance in comparison with research work on the *plant*.

I think you will agree that the trend of agricultural thought in the last half of last century was focussed mainly on the soil, but during recent years the focus of interest has changed. The centre of thought has been transferred from the soil to what is, after all, the most important factor of production, the living, energy-accumulating, food-producing plant itself. Various aspects of this have been the subject of most of the papers read at this Conference, and I need not elaborate them. I should like to emphasize this point, which is familiar to you all. I should like to have it ingrained into you that the study of the plant has become of much greater importance than even the study of the soil, because, after all, it is only to a limited extent, especially under the extensive method of farming that is so largely practised in Australia, that we can alter the physical or chemical character of the soil, and it seems to me that we are not likely to have in connexion with soil problems any new discovery as the result of research, that will be comparable with the effect of the use of superphosphate in our wheat districts, or the practice of fallowing. It is not likely—I do not say it is impossible—that any great advance is going to be made in connexion with the modification of our soil conditions, especially under our system of extensive farming; but if we have not the soil or the climatic conditions to suit the crop, we may conceivably be able to find or make the crop that would suit these soil and climatic conditions, so that the central theme of agricultural research has shifted from the modification of the soil to the improvement of the plant to suit environmental conditions which cannot be very materially altered. The modification of the plant comes under two main headings—the creation of new varieties by cross-breeding and selection, and the introduction of new plants and their acclimatization, both of which subjects have formed an important feature of the discussion at this Conference.

The successful work done with cereals, not only by the late William Farrer, but by many investigators, some of whom are present in this room, gives reason to hope that improvement may be brought about in almost every variety of cultivated crop by the application of the same methods, and this is important for the reason that I indicated the other day, namely, that there is a distinct danger of Australia becoming too much a one-crop country. There is a distinct danger at a time like this of "having all our eggs in one basket." There is a distinct danger in depending on a crop like wheat for export, because, as you know, wheat has not a very high value for its volume or even for its weight. I do not wish to be pessimistic, but we must face possibilities. Suppose the war should continue for a few years longer, and the building of ships should not greatly outpace the sinking of them by submarines, we must face the fact that for the next few years the shipping facilities may be quite insufficient to permit our new production of wheat and the accumulated stocks at present in Australia to be removed to their market overseas, and it is therefore important that, as a country dependent upon export to a large extent, we should aim at producing a greater variety of products, and especially products which have a high value per unit of volume. Butter, for instance, is better in that respect than wheat, and several crops that have been mentioned in the course of our discussions are also better. Tobacco formed a subject of discussion. Not only do we not export it, but we are importing it in large quantities, although it has been clearly shown that we have the soil and climatic conditions suitable for the growth of nearly every type of tobacco.

Then yesterday we had a very interesting account of the fibre plants from which it seems that the demand for flax fibre, particularly in the next few years, would be so great, and the price so high, that this industry could profitably be persevered with here, and the area under cultivation greatly increased. Since we are likely to become, whether we wish it or not, a country where more diversified farming must be practised, there is abundant opportunity for the improvement of varieties of every kind of crop under our local conditions. I have mentioned only these two crops, but there are many others which have been, or could be, profitably grown or grown more extensively—oats, barley, sorghums, millets, beans, peas, lucerne, rape, potatoes, pumpkins, sugar cane, and sugar beet, all of which are just as capable of improvement as wheat. Cotton is another instance of a crop which is receiving very considerable attention, especially in Queensland; and there are many reasons, economic and practical, why every encouragement should be given to increasing the acreage and production of that crop, and in this case also it is quite conceivable that the production of new varieties specially suited to our conditions will play a prominent part.

The improvement of varieties of crops is only one aspect of the research work that is being carried out, and should be carried out, with regard to the plant. Agricultural production would be very greatly increased if we could reduce the enormous damage done to crops by their natural or their unnatural enemies, and there is room for a great deal of research in connexion with the insect pests of the farm and the orchard, and even more so in connexion with the fungus diseases which take such a very heavy annual toll of our crops in all parts of Australia.

Then, amongst other natural or unnatural enemies, we have the subject of weeds. A further study of the characters of these weeds to find out their points of attack—the weak points in their armour—with a view to their eradication is also a matter upon which much more research could be profitably carried out.

Now, I have just indicated the general outlines of the field for agricultural research. The next question is important—Where is this research work to be carried out, and by whom? This is a matter which has been dealt with by Prof. Perkins, and I thoroughly agree with him in his opening statement that, where good work is going on, any interference of a red-tape kind should not be allowed. That the Agricultural Departments of the various States are doing excellent work in the way of agricultural research in its widest sense will be frankly admitted by any unbiassed critic. It would be difficult, indeed, to assess the monetary return which these Departments give for the money expended, but it must be very great indeed ; so that I contend that, whatever new organizations are brought into being, or whatever new scheme of Federal endowment is put forward, the work done by the Agricultural Departments should go on unfettered and free, and they should have a perfect right to expand their activities in any direction which they think fit. There is room for almost indefinite expansion, not only in research work, but in their equally valuable educational and administrative work.

In most States the Agricultural Colleges are associated with the Departments of Agriculture, and in some of the States at any rate the work done by them may be included under the same heading. Then, in recent years, there has been inaugurated a new medium for agricultural research, namely, the Universities, in several of which Schools of Agricultural Science have recently been established.

If there is any point that has been emphasized at this Conference more than another it is that there is a great need for trained men to carry out agricultural research, and the main function of the Universities will be to provide such trained men. There is no doubt that the more research work that can be carried out at the Universities the better ; but I would issue this word of warning, that too much in the way of research must not be expected from the Universities at their present stage of development, however much there may be in the future, because the number of students at the Universities does not justify the appointment of a sufficiently large staff to give spare time to the teachers to do much research work. I regret that this is so. It is extremely unfortunate, but it is, I think, inevitable for the time being. Of course the matter, even with a comparatively small staff, would be largely solved by the establishment of research scholarships—the research men to work under the direction and with the guidance of the teachers in the University Agricultural Departments. There is room for a tremendous amount of useful work in this direction. The field for research is infinite, and the facilities are increasing, but one of the troubles is this, that such men as would be prepared to take up these scholarships have turned their ploughshares into swords, and are engaged in another equally important kind of work at the present moment. I look forward, however, to the time when every University Department of Agriculture in Australia will have within its walls quite a small army of agricultural research workers. Although, perhaps, we may get some help from the Federal Government in this matter, I do not know of any more appropriate means by which wealthy citizens could perpetuate their names or more usefully serve their country after they have "shuffled off this mortal coil" than by endowing such research scholarships and fellowships. Australia has had some such benefactors ; but the wealthy men of Australia have in this respect done nothing approaching the good that has been done by their confrères in Canada and the United States. It is absolutely essential, as our Chairman has said, that research work should be carried out at the Universities. I should like to re-emphasize it from this point of view, that the student of agricultural science, whose life work is to be devoted to research, must be brought up in a research atmosphere. He must get to know something of the methods, and absorb something of the spirit of research, and that could hardly happen unless the University Department of Agriculture is the centre of research work itself.

Now, the first part of my paper dealt with agricultural research, and I have also been asked to say something about the *prevention of overlapping.* From my preceding remarks it should be obvious that, with such a vast field, there is not much danger of overlapping. I would not say there is no overlapping, but, as far as my observation goes, harmful overlapping at the present moment among the Agricultural Departments and other institutions engaged in research is practically non-existent. It is true that, for instance, we have wheat breeding going on in Western Australia, South Australia, Victoria, New South Wales, and Queensland, but I would not for a moment call that harmful overlapping, because each State has its own problems to solve and its own difficulties to overcome, and in an important subject like this the more people working on such problems the better chance of successful results. What is wanted is not so much the prevention of overlapping as some sort of co-ordination of effort and correlation of the work of different Departments. In attempting to bring about such co-ordination and correlation it would be of great importance that the point mentioned by Prof. Perkins should be borne in mind, namely, that there shall be no attempt to shackle agricultural research, no attempt to relegate it to watertight compartments, or to prevent individuality of effort. It seems to me, however, that something more could be done in the way of co-ordination, and in my opinion an excellent step has been made by the holding of a Conference, such as this. Very useful co-ordination work could be done by holding similar Conferences, perhaps of a more limited nature. The officers who are doing similar work, not only research work, but also routine work, in different States might meet from time to time in order to exchange views. An important question, for instance, has arisen recently in connexion with the standardization of methods of determining the milling qualities of wheat. The coming together of experts on each subject for the purpose of comparing notes might help greatly in difficulties of that kind ; just as the plant breeders who are present at this Conference have benefited by their visit to this Conference and to Werribee Farm, and by the free exchange of opinions both in set papers, discussions, and private conversations. There is undoubtedly room for work of that kind.

The question is—What is to be the co-ordinating body ? Personally, I think that this is one of the most useful functions of the recently-instituted Advisory Council of Science and Industry, which was the means of calling this Conference together, and which proposes to do similar useful work in other directions. This Advisory Council of Science and Industry, as you know, is only a temporary body, preparing the ground for the proposed permanent Institute of Science and Industry, and that Commonwealth Institute will devote a good part of its energies to co-ordinating and correlating the research work carried out in the different States, and also superintending the investigations which are too big for any one State to carry out—problems like the tick pest and prickly pear pest. But if we look into the future, we seem to see something like this—This Commonwealth Institute of Science and

Industry dividing itself into its two natural parts; one to deal with the pastoral and agricultural industries, and one to deal with the secondary and mining industries. And it is quite conceivable to me that, out of the agricultural and pastoral section, there may arise something of the nature of a Federal Department of Agriculture, the creation of which has been suggested from time to time. The lines upon which that Department should work require very serious consideration. The working of the Federal Departments of Agriculture in Canada and the United States should be very carefully studied, and particularly in regard to their relationship with the State Departments of Agriculture and State Agricultural Colleges, and a very careful lookout should be always maintained to avoid the difficulties which our Chairman mentioned in the beginning of his address.

I offer these few somewhat general and rambling remarks in the hope that they may give rise to a useful and profitable discussion.

Discussion of Papers by Prof. Perkins and Prof. Watt.

Prof. Paterson said that the subject of these two papers was the most important with which the Conference had to deal. They opened up very large questions which require to be carefully considered. Research is now considered necessary in the manufacturing industries and in agriculture research is particularly essential for the reason that the raw materials which the farmer uses are more complex and less uniform in character than are the raw materials of the secondary and manufacturing industries.

Prof. Watt had enumerated, under the heading of "The Soil, the Plant, and the Animal," subjects which might usefully form a subject for agricultural research. Those who were daily employed upon these subjects and their teaching knew that their number was practically infinite. He could imagine no more impressive lesson to the layman in agricultural research work than the study of, say, the *Experiment Station Record* issued monthly by the United States Department of Agriculture, which gives brief summaries of several hundred researches in agricultural science which are completed each month. The agricultural scientist has therefore an abnormally wide field to work upon. For practical purposes, we were less concerned at the moment with the subjects which awaited research than with the way in which agricultural research generally should be carried out, and the relation of the State authorities to the proposed Commonwealth Institute of Science and Industry, or alternatively the Commonwealth Bureau of Agriculture. He strongly agreed with Prof. Perkins' view that the leader of an experiment station should be a fully qualified practical agriculturist. We all knew the often contemptuous and frequently sneering attitude of the practical farmer on the one hand, and the pure scientist on the other, towards agricultural research. When we looked to the history of what had gone before, he was not quite certain that this popular attitude was altogether unjustified. The pure scientist was almost certain to draw the wrong conclusion and, therefore, he was very strongly of opinion, indeed, that the leader of an Agricultural Research Station should be a man who was fully qualified in practical agriculture.

A good deal could be done by men who knew something of practical agriculture, and had a fairly good training in general science, to break down this popular prejudice. He had experienced this himself, and was pleased to say that agricultural science was now considerably more respected in Western Australia.

A good deal had been said by both the speakers as to the desirability of giving the research worker a free hand. In his opinion, it was impossible to dogmatize about this, because different individuals required different treatment, and if some people were given a free hand, it would almost certainly involve the waste of public money. In other cases, if they were not given a free hand, their action was likely to be hampered. He thought it was most desirable, as far as State activities in agricultural research were concerned, that an endeavour should be made to bring these as far as possible under the jurisdiction of an experienced committee. Not only was a committee wiser, if given time, than an individual, but the individual was liable to death or removal, and if too much of the control of State activities was in the hands of one man, a time might come when the State would sincerely regret its short-sighted policy of the past.

There were a number of advantages in Committees of Research. No one man could presume to be fully up-to-date and conversant with the latest phases of research in each part of a large subject like agriculture. But a Committee of Research would work along systematic lines. In the first place, it would be open to receive suggestions from its members as to useful topics for investigation. It would then discuss these generally, and ask one member to draft proposals for carrying them out. These would be passed by the Committee, and attain to the dignity of projects. These projects would be assigned to certain individuals to carry out under the management of the Committee. Then the Committee would keep records of the work which had been done, and would publish systematic reports from time to time in a way which had been somewhat practised in New South Wales, and also used in some of the other States. Such a Committee would give frequent and free acknowledgment to the subordinate workers who were carrying out investigations, because nothing was more hampering and paralyzing to genuine research work, than a feeling of jealousy among workers in the same field, that their ideas might be borrowed, or might not receive full recognition.

Passing from the question of State conduct of research, which it was only possible in the limited time to deal with very generally, he would now refer to the relations which may be desired between the Federal body, whether it be an Institute of Science and Industry or a Commonwealth Department of Agriculture, and the State Research Committee.

He believed that the control of ordinary agricultural research work should, as a general principle, be in the hands of the State authorities. He was of opinion, however, that the Federal body ought to assist in the conduct of agricultural research work. There are two ways in which they might do this. On the one hand, they might vote grants to the State authorities for the conduct of research upon certain approved projects, which would first have been submitted to them, and the continued payment of these grants would depend upon satisfactory reports from a Federal officer, who would be enabled to visit the States and receive any information bearing upon the subject which he desired. Another way in which the Federal body could assist would be by establishing its own laboratories for investigations of more difficult problems of a general nature which were important to all the States. There were a number of subjects of agricultural research which required highly trained specialists for their elucidation—men of the kind who were not usually found in an ordinary State Department of Agriculture. Obscure problems in organic chemistry, and obscure problems relating to the stock and animal industry, problems which were of general importance, could best be solved in a Central Laboratory. Both speakers had mentioned that the conduct of agricultural research must depend to a considerable extent upon having a proper system of agricultural education. Trained workers were necessary to obtain good results. Agricultural education was intimately related with the future of agricultural research. In Western Australia they had been giving a good deal of attention to this subject, and they had at present an influential Committee investigating the whole problem of agricultural education within the State. In his opinion, agricultural education might be classified in several ways in regard to its object and its degree. In the first place there was agricultural education in the University, which led towards a degree and produced professional experts, who would be valuable for different branches of research. This was the fundamental object of University education in agriculture—to produce agricultural professional experts. All the students who go through a regular course in the University would not be suitable for research work on any independent basis. Only a proportion of those who go through would be really useful men. Another type of agricultural education was provided by Agricultural Colleges, and the fundamental object of the Agricultural College was to produce good farmers, not agricultural experts. They would not advance so far in pure science and would not require the fairly severe matriculation requirements, the essential object of the Agricultural College being to produce better farmers. Then there was a third and lower type of agricultural education, namely, such as was given in the secondary and primary schools. Here the object was general education, because practical agriculture could not be taught to boys. The object in school teaching of agriculture was to provide a course which would be generally educational and train the mind of the scholars, so that they would reap advantage whether they afterwards went on the land or not. He firmly believed that agricultural science could be used to train the mind of our youth in a way which was, certainly, as good as the ordinary subjects taught in a school. As far as agricultural science was concerned, we were principally interested in the University phase. University teaching of agriculture should have some research work in connexion with it, but, unfortunately, the number of students in the Universities at present only permitted of a small staff, who had their hands quite full with the educational part of the course. Experiment stations were required in connexion with the Universities. The advantages of this would reveal themselves not only in the students, but also in the teachers, for there was nothing which so sharpened the interest of the teacher as to come into direct contact with research work. It kept him alive, thoroughly up-to-date in his work, and if it was possible, helped to sharpen his mental qualities.

In Germany, agricultural research formed an essential part of the University curriculum. In Germany a University degree could only be obtained by working upon some research, usually for a couple of years after finishing a course, which was equivalent to a degree here. The degree was obtained by working upon some research approved by the Professor of that subject, taking as a rule about two years, and the degree given upon that. The lack of funds prevented the carrying out of our ideals at this time, but we ought to hold it in view, as one of the objects to be aimed at in the future, that every University Department of Agriculture should be fully equipped with an up-to-date Research Station.

Dr. Green agreed that the University was the natural training ground for research workers. He pointed out that there was one very big difference between agricultural research work and other kinds of scientific research, in that a piece of research work in other subjects could usually be carried out by one man, generally without any very large expenditure, but agricultural research work generally meant that a farm must be kept going continuously. University students should be taught how to do research work. In their final stages they should be immersed in a research atmosphere, and should be given a knowledge of exact methods. This was work that, in his opinion, could be best taught by a study of the more exact sciences. Applications could be best learned outside the University, but if they did not learn exact methods in the University, then they would never learn them at all. There would always be exceptional men who will learn anyhow, but he was speaking of the average man.

Prof. Watt had urged that a soil survey should be started, but we really did not know how to make use of the results of a soil survey at present. He agreed, however, that existing data should be collected, because in the near future it might be of importance, and the work should be started at once, so that we could take stock of some of the natural vegetation which was observable on our soils before it was too late.

Mr. Pye emphasized the necessity of interesting the general public through the press in research work. He thought that the Universities could not be expected to turn out research workers until they had some sort of experimental farms for training students in agricultural research. He agreed with Prof. Watt that Australia was too much dependent on one crop. Owing to this predominance of interest in wheat, little experimental breeding of other crops had been undertaken, but the successes achieved in wheat-breeding should stimulate others to work on other crops.

Mr. McAlpine said that, if possible, the research worker should be able to devote all his time to one problem; he must be an enthusiast, and in agricultural experiments he should be a local man with experience of Australian conditions.

He thought that a scheme might with advantage be drawn up by a committee, indicating what experiments in connexion with the soil, the plant, and the animal were desirable.

He also urged that young Australians should be given travelling scholarships, so that they could gain experience in other countries. This would be more economical than importing experts from other countries, who usually failed, owing to their ignorance of local conditions.

Mr. Sutton thought that in addition to training research workers, the University course should aim at attracting the sons of pastoralists and the wealthier agriculturists, who would be likely to take a prominent part in the future development of the country, and who should benefit greatly by such a course. In a country like Australia, so dependent on agriculture, a knowledge of the rudiments of the subject was of value to men in every walk of life, and, therefore, in Western Australia they were introducing elementary agricultural science into the school curriculum.

He was a strong believer in an Experiments Supervision Committee. In his opinion, such a Committee should not in any way shackle real research work, and the enthusiastic research worker should be only too glad to have behind him a sympathetic committee, to whom he could apply for advice and assistance. Apart from real research work, however, much experimental work had been undertaken for demonstration purposes, in the past often by untrained men, and an Experiments Supervision Committee was an inportant check on unnecessary work of this nature, and resulted in much public money being saved.

Mr. Richardson said that the Conference was indebted to the preparers of both papers for the comprehensive manner in which they had treated the subject. In addition to research under the heads named by Prof. Watt—the soil, the plant, and the animal—there were other subjects on which research might well be undertaken; for instance, the study of the relationships between land, labour, and capital, and these should also find their place in the University course. Prof. Watt had referred to the necessity for increasing agricultural production in Australia. This involved not only further research for the discovery of new knowledge or new applications of existing knowledge, but also the dissemination of the facts that had already been discovered among the farmers. In order to put into practice the principles already discovered, it was necessary to have trained individuals who could interpret the teachings of science in a simple, straightforward manner to the practical farmer. The training of individuals in Universities played an important part in disseminating this knowledge. The only way to get a genuine and permanent increase in agricultural output was to apply the results of agricultural research. The stimulus given to agriculture by bonuses, or any other methods, was largely artificial and was not permanent. The diffusion of scientific principles among the farmers was, in his opinion, as important at the present time as the discovery of new facts, and, therefore, he maintained that the agricultural course at the Universities should not aim merely at producing expert scientists, but should turn out men who would be the leaders of agriculture in their various districts.

Mr. Richardson pointed out that the agricultural student who obtained his degree was at a great disadvantage compared with those who obtained degrees in other applied sciences—medicine, engineering, or veterinary science. He did not become a member of a closed profession, and could not put up a brass plate. He maintained that it was essential that some system of scholarships for such men should be established or that they should be assured of positions in the State Departments of Agriculture or under the Institute of Science and Industry.

Twenty-five years ago, the average production of wheat, rye, barley, and potatoes in Great Britain was far ahead of that in any other country, and 75 per cent. greater than that of Germany. Since then, Germany had enormously increased her production, and now stood in front of every agricultural country in the world. This advance had been effected by the exhaustive studies of principles in the Universities, where men were trained, who were subsequently distributed throughout the country.

In connexion with agricultural education in schools, he stated that in Victoria efforts had been made to get students at the Melbourne public schools to take a course of agriculture at the Burnley Horticultural Gardens. Last year 126 students had taken up the course for the Junior Public Examination, and next January about 220 would begin the course. A very fertile mine of potential agriculturalists had thus been tapped, but it was necessary to see that those who completed their course in agriculture obtained adequate remuneration, as this would encourage others and secure a supply of trained men.

Prof. Watt, in replying, referred to the question of agricultural scholarships, and said that the Royal Agricultural Society of New South Wales had awarded a scholarship from the Hawkesbury Agricultural College to the University of Sydney, tenable for three years. This was on the lines advocated by Prof. Perkins. He thought that in view of the profits made by Royal Agricultural Societies, it was clearly their duty to assist in this way. He thought also that wealthy men, who had made their money on the land, should be induced to endow such scholarships, though at the moment the scholars felt it their duty to enlist, instead of continuing their work. He agreed with Mr. Sutton that the agricultural course in a University was the best course for the sons of wealthy men, who intended to make their living on the land, and but for the war they would probably have had a number of such students at the University of Sydney.

It had been said that in starting agricultural departments in the Universities, Australia was ahead of the times. Many American Universities had ten times as many teachers in their Agricultural Departments as there were agricultural students in all the Universities of Australia. As a matter of fact, we were far behind the times in this respect.

With reference to the control of experiments by Advisory Committees, he considered that this was sometimes a good thing, and sometimes a bad one. In cases such as Mr. Sutton had instanced, where men without much training were attempting to carry out research, a committee was obviously of value, but really good research workers were so rare that it would be a great pity if they felt shackled in any way by an unsympathetic committee.

He did not agree with Mr. Richardson when he seemed to belittle the immediate need for an increase in agricultural research. While it was true that many results of research had not yet been put into practice, and while he agreed that the Universities should turn out men capable of interpreting these results to the farmer, he held that the carrying on of additional research was at least as important as the evangelizing work.

Prof. Perkins, in replying, said that he wished to make clear that he had not intended his remarks about agricultural education to be taken as applying to the whole field. There was no doubt that this was a subject of great national importance, but it was not the question under discussion. He had been asked to deal with agricultural research, and he had assumed, therefore, that the Advisory Council of Science and Industry agreed that there was need for agricultural research in Australia; judging from speeches made by the Prime Minister he assumed also that the Commonwealth was prepared to assist agricultural research. Before agricultural research could be undertaken, it was necessary to obtain research workers, and, therefore, it was logical to commence by a consideration of the steps necessary to provide these. From this point of view, he had discussed the provision of scholarships from the Agricultural Colleges to the Universities, but he had not meant to deal with the general subject of agricultural education, and his remarks were to be taken only as applying to the education of research workers. Prof. Paterson appeared to have misunderstood this, and had discussed agricultural education generally. He did not propose to follow him outside the field of discussion, but he desired to say that he did not agree with the introduction of agriculture or agricultural science into primary or secondary education.

He hoped that the Commonwealth would be able to endow research, and he felt positive that, in order to do this, it would be necessary not only to train men in research, but also to find occupations and suitable emoluments for them as soon as they had completed their course.

Whilst men who took up such work were not necessarily looking for money they must obtain a reasonable living wage. Men who were undertaking research work were really continuing their training, and if they were successful, their work should lead to their securing better positions later.

RESOLUTIONS.

(A number of the following resolutions were proposed at the earlier sessions of the Conference and were then carried provisionally. All the resolutions were finally adopted at the last session.)

1. This Conference recommends to the Executive Committee of the Advisory Council that a "Seed Improvement Committee" be formed under the Council.

This Committee should, among other matters, deal with—

(*a*) The nomenclature of cultivated varieties of farm crops.
(*b*) The elimination of undesirable varieties of crops.
(*c*) The exchange and dissemination of seed samples for research work.
(*d*) The recommendation of money grants to approved State or other institutions for work in connexion with seed improvement and the introduction of improved varieties of crops.

(*Moved by Prof. Paterson, seconded by Prof. Watt. Carried unanimously.*)

2. That, in view of the benefits to be derived from the systematic introduction of seeds and plants into the Commonwealth and to ensure more economy of effort in this direction on the part of all the States, this Conference is of the opinion that as soon as practicable a Plant Introduction Bureau should be established the functions of which would include :—

(1) Arrangements for the introduction of new and useful agricultura plants from other countries into the Commonwealth.
(2) The systematic testing of these introduced plants in co-operation with State Experiment Farms.
(3) The systematic recording of the results of such tests.

(*Moved by Mr. Sutton, seconded by Mr. Easterby. Carried unanimously.*)

3. That this Conference recommends that each State Department of Agriculture should continue or initiate the work of improvement and selection of its cultivated crops as part of its regular work, and that such work of improvement be on uniform lines in all the States.

(Moved by Mr. Pridham, seconded by Prof. Flynn. Carried.)

4. That the rust in cereals, particularly black rust in wheat, which is common in all the States and in some seasons largely reduces the yields, be made the subject of a special investigation in connexion with plant breeding.

(Moved by Mr. McAlpine, seconded by Mr. Sutton. Carried unanimously.)

5. That the Executive Committee of the Advisory Council be asked to arrange for an annual meeting of plant breeders from the different States with a view to co-ordinating their work, and arriving at a uniform policy without interfering with individual methods. The meeting to be fixed at a convenient season of the year (July).

(Moved by Mr. Pye, seconded by Mr. Quodling. Carried.)

6. That this Conference recommends the establishment of an organization to deal with the collection, propagation, improvement, and cultivation in suitable areas of the most promising indigenous grasses and fodder plants.

(Moved by Mr. Quodling, seconded by Mr. Pye. Carried unanimously.)

7. That this Conference recommends to the Advisory Council of Science and Industry the advisability of closely investigating the tobacco industry in Australia both in the interests of the producer and with a view to retaining locally the profits of manufacture.

(Moved by Mr. Smith, seconded by Mr. Quodling. Carried unanimously.)

8. That in view of the high prices ruling for fibre products and the desirability of making Australia self-contained in the production of fibre, the Conference recommends the Advisory Council of Science and Industry to make a thorough investigation into the possibilities of fibre cultivation in Australia, particularly flax and sisal hemp, and the possibilities of producing these fibres for local manufacture or for export.

(Moved by Mr. Richardson, seconded by Prof. Paterson. Carried unanimously.)

9. That the Advisory Council of Science and Industry be asked to ascertain whether the British Government would be prepared to purchase dew-retted flax fibre from Australia in 1919 ; and, if so, what quantities and at what price f.o.b.

(Moved by Mr. Sutton, seconded by Mr. Richardson. Carried unanimously.)

10. The Conference is of opinion that the prospect of commercial production of power alcohol from certain crops is promising, and suggest that special experiments should be arranged by the Advisory Council of Science and Industry to determine the actual yields of alcohol obtainable from these crops, including sorghums in various stages of development.

(Moved by Prof. Paterson, seconded by Mr. Quodling. Carried unanimously.

11. That this Conference welcomes the proposal of the Advisory Council to investigate the utilization of Australian phosphates, and suggests that this investigation should include manurial trials, particularly on pasture lands, in those of the States which possess such phosphates.

(*Moved by Prof. Paterson, seconded by Mr. Pye. Carried unanimously.*)

12. That, in view of the need for a supply of scientific investigators into agricultural and pastoral problems, the Advisory Council of Science and Industry be requested to direct the attention of the various Australian Universities to the subject.

(*Moved by Mr. Sutton, seconded by Mr. Pye. Carried unanimously.*)

13. In view of the prominent position occupied by the United States of America in scientific and practical agriculture and of the similarity of the climatic and economic conditions of that country to those of Australia, this Conference recommends the early appointment of a permanent agricultural representative from Australia to the United States whose duties should include keeping Australia in touch with improved scientific and practical methods in agriculture and the supply of promising varieties of cereals and other crops.

(*Moved by Mr. Wenholz, seconded by Prof. Paterson. Carried unanimously.*)

14. That this Conference expresses its appreciation of the action of the Executive Committee of the Advisory Council of Science and Industry in calling it together, and is confident that the opportunity of meeting and consulting together thus afforded to agricultural scientists from the different States will be beneficial to agricultural progress in Australia.

(*Moved by Mr. Sutton, seconded by Mr. Easterby. Carried unanimously.*)

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