ENVIRONMENT IN RELATION TO CROP IMPROVEMENT.

R. A. CALDER, Field Crops Division, Plant Research Bureau, Palmerston North.

THIS paper is presented with the idea not of delivering any dogmatic statements nor of suggesting anything original ; it merely offers some comments on the relationship between environment and crop-production, discusses the effect this relationship has in, regard to crop-improvement work, and considers the type of organization which may be suitable for a comprehensive plant-breeding policy.

During the last few years many different field crops have been grown at Palmerston North by the Field Crops Division of the Plant -Research Bureau for the purpose either of classification and identification or of providing foundation material for breeding purposes.

The varieties and strains of the different species grown were sufficiently varied to have produced striking contrasts, and it is upon the evidence of these diversifications that the following remarks are based. Grasses and clovers have not been referred to, but it is probable that the generalizations made apply equally as well to these species.

EVIDENCE.

Lucerne.-A number of varieties of lucerne were introduced from countries experiencing different climatic conditions. These were grown together in a comparative trial. and the contrast in the behaviour of certain groups indicated, to some extent, the distinct ultimate responses of a species consequent upon its production for numerous generations in particular habitats.

Types originating from regions experiencing a warm. winter climate were tall, erect, quick growers, of rapid recovery, and had a tendency to continue growth during the winter months ; varieties from areas subjected to cold winter climates, on the other hand, were flat, spreading, rather slow growers, and winter dormant.

Such diverse forms may be useful introductions if variations in particular directions are required, but if their modifications are too extreme their economic value is somewhat restricted. For instance, the cold-winter-climate varieties are able to withstand severe winter conditions, but are winter dormant and produce little herbage in the late autumn and early spring. Conversely, the warm-winter-climate types tend to continue growth throughout the year, but are liable to be killed out by hard frosts.

The varieties most suited-to local conditions were those which-had been developed in temperate or subtropical zones-that is, in environments somewhat similar to those of the trial ; these gave the greatest seasonal production. Forms like Marlborough, South African, and Hunter River, evolved in more or less temperate regions, greatly excelled in seasonal productivity such types as Ladak, a cold-winter-climate variety, or Arabian, a warm-winter-climate one.

Representatives of these different forms have been under observation for six years, and, although the quantitative--i.e., size—characteristics have been subject to fluctuation due to different soil

or climatic conditions, yet their habits of growth or qualitative characteristics have remained more or less unchanged. The size of a plant is altered more easily by the environment than its habit of growth.

Yellow-fleshed Turnips.—The growing' of roots for the purposes of classification and identification has been conducted periodically. Swedes and white-fleshed turnips generally yield particularly well ; yellow--fleshed turnips are nearly always a failure. In Otago and Southland, however, this brassica, when not infested with club-root or diamond-back moth, produces good crops.

These facts, together with the knowledge that the crop is a popular one in Scotland, lead to the supposition that the type has been evolved to suit, more especially, those areas with comparatively cool climates and long days. When grown out of such an environment, some physiological rhythm is upset and the full productive capacity of the species cannot be realized. It is a case where again the qualitative characters remain unchanged, but where the quantitative abilities are affected not so much by soil conditions as by such external influences as temperature and light periodicity. Perhaps adequate prcsowing treatment of the seed might afford the necessary requirements and a satisfactory crop be secured even at Palmerston North ; this has not yet been attempted.

Soya-beans.-This crop was grown only in 1935–36, but its behaviour presents another good example of the limitations imposed upon a species by the nature of the growing-season. Early, midseason, and late varieties were sown. These matured according to the sequence observed in other countries, but, whereas satisfactory seed-yields were obtained from the early and midseason types, the later ones, although the heavier forage producers, were only beginning to develop pods when they were destroyed by early frosts. These late varieties, to set seed satisfactorily require shorter days and warmer temperatures than are prevalent in this district. Presowing treatment may possibly tend to overcome this handicap.

Oats.-Numerous varieties of oats have been studied and compared for some years. Algerians has invariably been the most suitable. The reason for this has been not entirely a matter of growth habit. This. variety is less susceptible to rust attack than arc many others, and, as rust is an ever-present malady in the district, the growing of certain types for seed purposes, at least, is practically prohibited. Disease incidence is an environmental factor influencing crop-production.

Swedes. --At Palmcrston North most varieties of swedes, under normal conditions, can be expected to give fairly satisfactory -yields. In certain parts of Canterbury, however, unfavourable conditions-chiefly lack of rainfall at critical periods, and infestation by aphis, diamond-back moth, or' grass-grub-restrict the capabilities of this valuable forage crop. External forces. common to the habitat create a situation inimical to the optimum development of the species.

Potatoes.-For many years the value of growing potato " seed " -in Scotland for crop-production in England has been. fully recognized. Similarly, potato " seed " from certain parts of the South Island is superior to that produced from most of the North Island lowland potato-growing areas. This is due not to any advantageous

physiological effect engendered in the plants by the environment, but to the fact that, in the colder regions, the spread of virus disease is checked by the natural control exercised on the carriers by the climatic conditions. Conversely, in districts where " degeneration " is very rapid conditions are more favourahle for the distribution of the infection. Again, factors associated with the environment are responsible for limitations in crop-production.

This, then, is the evidence. Further relevant cases could be cited, but those described should be sufficient to indicate the definite effects exercised on crop-production by external influences.

DISCUSSION.

(1) Environment in relation to Qualitative or Habit of Growth Characteristics.

From the' distinct behaviour of the various lucerne types it appears as if different environmental conditions do induce in a species different reactions. Crops, confined for very long periods of time to a particular habitat, do adjust themselves to suit the conditions, and then, when removed to a different environment, tend for some time, at least, to exhibit in their progeny their adapted habit of growth. It is not, perhaps, a matter of external conditions affecting the gcnetical constitution ; rather is it a natural selection and subsequent concentration of desirable characters already present. " The method of the adjustment of an ecotype to its environment is a matter of controversy. The view generally held by experimentalists lays emphasis on the selective effect of the environment-that is, the elimination or suppression of some existing plant constituents and the favouring of others. Certain ecologists, on the other hand, assume directional changes .in accordance with the theory of acquired characters " (Gregor and Horne). The former view is supported apparently by Student, who states, " And so we reach the conception of a species patiently accumulating a store of genes of no value under existing conditions, and, for the most part, neutralized by other genes of opposite sign. When, however, conditions change, unless too suddenly, the species finds in this store genes which give rise to just the variations which will enable it to adapt itself to the change."

This theory could thus account for the development of the contrasting lucerne types. They have been evolved to harmonize with particular surroundings, and, while existing in such habitats, maintain their modified forms. When transferred to a different environment, these forms must be reproduced until such time as the species is able to readiust itself. Thus, although external forces do exert a determining influence on the qualitative characteristics of a species, the effect is delayed ; for short-term investigations habit of growth may be regarded as more or less stabilized. At all times, on the other hand, the circumstances of the environment tend immediately to modify quantitative characters.

Again, the above concept leads to the contention that plant material being introduced or being collected for selection purposes should be chosen from regions experiencing climatic conditions somewhat similar to those in which the species in question is to

be grown. Such material will 'already have become conformed to suit the particular surroundings, and should ensure that satisfactory results will be more definite or will be secured more rapidly. Regarded merely as introductions, South African and Hunter River lucernes were of much more value than either the cold-winter-climate or the warm-winter-climate forms. For breeding purposes, extreme introductions may occasionally be desirable, but, apart from such special requirements, perhaps even breeding-material were better collected from corresponding climatic regions. All our lucerne breeding-work is being carried out on Marlborough strains or allied types.

(2) Environment in relation to Quantitative-i.e., Size-Characteristics.

Soil conditions, temperature, light, amount and periodicity of the rainfall, the duration of the growing-season, and the prevalence of disease and insect pests are all factors which in some degree tend to determine plant growth and behaviour.. As the plant develops, each of these factors exerts some influence on the final , expression of all yield characteristics.

Throughout the plant kingdom certain crops have become reasonably well adapted to suit certain conditions. Often, though, their maximum potentialities cannot be realized owing to the presence of some external force which restricts their full development : a few examples have already been considcrcd.

(3) Methods employed to counteract the 111 Effects of Adverse External Conditions.

In many cases artificial remedies may be employed to cure the ill -e.g., the application of fertilizers and of sprays or the presowing treatment of seed--but where such operations are either not effective or not possible other methods must be adopted. One of the chief of these is, by selection or breeding, to raise strains or develop varieties which are better able to contend with the particular limiting factor. This is made possible by the peculiar behaviour and construction of that mechanism which is responsible for the reproduction of the species.

All plants are liable to develop variations in some form or another -they may be frequent occurrences or may appear only at odd intervals ; they may be transmitted to future generations of they may be confined merely to one individual ; and they may be desirable or undesirable.

Selection affords the opportunity for isolating, testing, and multiplying those ndividuals possessing variations which may enable them to compete more successfully against the adverse effects of some particular external force.

The process, however, merely chooses desirable forms from what is already present ; it cannot create anything new. This may be accomplished by hybridization, a function of which is to effect the combination of certain qualities otherwise distributed among different forms. If suitable parents are utilized valuable segregates may be obtained.

By either of these methods, then, it is possible to raise forms which, both morphologically and physiologically, are better suited to a parti-

cular environment than the already existing types. Early maturity, disease resistance, ability to withstand drought, and adaptability to other climatic vagaries are some of the characteristics possessed by certain crops bred particularly to withstand the detrimental influence exercised by some particular limiting factor.

Work of this nature is being conducted by the Field Crops Division of the Plant Research Bureau on such crops as lucèrne, rape, oats, peas, turnips, and swedes.

CONCLUSIONS.

From the profound effects which the environment has on the ultimate expression of a plant's constitution, and considering that most selection or breeding efforts are directed against the effects induced by some external influence, it is suggested that, ideally, in any particular country, crop-improvement operations should be conducted only in those districts in which the crop is to be grown. This is rather impracticable, though, and a more feasible 'scheme has to be adopted.

The main work must be centralized in that locality most suitable to the majority of crops being handled ; here, the initial stages and the preliminary eliminations should be carried out. Subsequent to this step, promising selections or segregating-materials should be tried out at branch stations specially established for the purpose. These subsidiary stations. must be limited in number, for economic reasons, but they should be so distributed that the localities in which they occur arc representative of the main agricultural pursuits. By this means crop improvement is not confined to one particular district-it becomes a comprehensive policy. It also ensures that plants introduced from other countries would be subjected to more widely distributed tests.

Such a scheme has been functioning in Sweden for some years now. "The principal station and the central administration of the Swedish Seed Association is located at Svalof, where most of the breeding-work i s conducted. . The activities of the plant-breeding institute are distributed between the central station at Svalof and several branch stations in different parts of the country. Some of the branch stations have been founded by the Association with. a view to obtaining wider climatic and soil limits for the purpose of testing, but others were set up at the request of the agricultural societies of the respective districts. Their task is to test varieties bred at Svalof or at other places, and also to breed for local purposes, ***as far as possible using local plant material.*** The branch stations are distributed in such a way that each represents one of the most important agricultural districts."

The foundations of such an organization have already been established in New Zealand;-but could probably be extended with much advantage to the farming community. Central stations have been formed, and there are a few areas available for testing out material. These areas are, however, either farm schools or demonstration farms; they are connected only indirectly with the central stations, and have been inaugurated for purposes other than plant-breeding. The system, as it is, is, therefore, not quite satisfactory to either body. What is required is that definite small areas should be made available-they may be attached to the already existing ones-and that the trial of such material as has been discussed should be regarded as a distinct function

for which the necessary facilities should be provided. Although in New Zealand there is considerable variation in soil and climatic conditions, yet certain limits exist beyond which it would be unnecessary to go in an attempt to secure satisfactory representation. The following centres probably would serve-(I) Bay of Plenty : Tauranga ; (2) Waikato : Ruakura ; (3) Manawatu : Palmerston North ; (4) Canterbury : (n) Lincoln, (b) Rangiora or Timaru ; (5) Central Otago ; (6) Southland : Winton.

If recognized areas could be set aside in these localities, and if facilities were made available for the testing of plant material, it would aid considerably towards the servicing of the plant-breeding and the plant-introduction activities of all interests.

DISCUSSION.

Dr. Hilgendorf : The paper tends to indicate that Mr. Calder has been trying to write " down " to his audience; he has prepared a scientific paper based on scientific knowledge which he has been trying to make understandable generally, and he has made inaccurate statements which will not bear scientific investigation. It is one of the faults of the Grassland Conference that we have developed into a meeting for extension of information, rather than a meeting for scientific discussion. We have to discuss whether we have developed in the right lines. I am sure Mr. Calder will not think I have criticized harshly. It is one of those papers which has made a concrete suggestion for the improvement of the science in which he is so interested.

Dr. Frankel : I wish to associate myself whole-heartedly with the suggestion made by Mr. Calder. I have felt for some years that **our** knowledge **of** the ecology of this land we are trying to serve is so incomplete that it seriously handicaps our work. The suggestions which Mr. Calder made would, in **my** opinion, quite cover the field. All of us who are concerned with plant-breeding have made mental ecological maps as it were. I suggest we all work together and that we lay down these mental maps. Dr. Hilgendorf has made pioneering steps with grasslands maps ; Mr. Holford has mentioned the question of manure-response maps.

Dr. Yeates : Mr. Calder's paper dealt with the ecological aspect of plant-improvement—in other words, the limitations of any one crop under any one set of conditions. In this country we have no one who has really specialized in the subject of plant physiology. All the larger and older countries, such as Russia, which is carrying out extensive programmes of plant-breeding, also has very well-developed branches of plant physiology, and in New Zealand we certainly do very much need some such development in plant physiology.

Mr. Levy : I would like to support Mr. Calder in his paper. I think the general principles underlying Mr. Calder's paper are correct, even though Dr. Hilgendorf may have taken some exception to the way in which they have been expressed. There is *no* doubt, to my mind, that environment unquestionably does influence plant-life. We have in New Zealand very fine examples of that. We have studied rye-grasses from different parts of the world. We have not met quite the type which has evolved in Hawke's Bay. We have studied white clovers. We have not met quite that type which has evolved in Hawke's Bay under certain conditions and again *in* certain parts of Canterbury.

Mr. Cockayne : Regarding the use of the term " ecology " and Dr. Yeates's remark that we have a considerable number of ecologists, if we have a number of ecologists it must be remembered that their only possible scope is the field ecology, which my father spent his life on. The individual cannot cover too wide a field—he must have assistance and he must have a specialized orbit, and many of the features which the ecologist in New Zealand is endeavouring to cover have to be handed over to other people. The essential feature in progress, in knowledge in any direction, is team work and co-operation.