PERSPECTIVES IN PASTURE PLANT BREEDING IN NEW ZEALAND

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After about a quarter of a century of pasture plant breeding in this country it is wise to attempt some evaluation of the plant improvement studies under way at present and projected for the future. Grasslands Division, largely through the efforts of Dr L. Corkill, has released, up to the present, eight improved varieties into the Government Certification scheme. These varieties have proved themselves in most parts of New Zealand to be superior to commercial varieties of New Zealand origin and to any introductions. The question is what further problems can we hope to solve by plant improvement methods. I propose to discuss briefly three main topics: Objectives of Selection, The Raw Material of Selection, and Methods of Breeding.

Objectives of Selection

Of the many breeding objectives which concern us, including breeding for resistance to disease or insect attack, breeding for increased vigour, or persistency, or seed production, I propose to stress four which may not be mutually exclusive:

(1) Breeding for extended season of growth.
(2) Breeding for improved efficiency of utilisation of water.
(3) Breeding for quality.
(4) Breeding for competitive ability.

First, breeding for extended season of growth. This is a field in which I consider we can hope to make considerable progress. It would seem that most of our pasture plants were originally introduced into New Zealand from England or from northern European countries, and have an attribute, winter dormancy, that would assist them to survive the cold winters in the countries from which they come. Even species that seem to have adapted themselves well to New Zealand conditions, such as white clover and *Lotus uliginosus*, have little winter growth when compared with recent introductions from Mediterranean countries, such as Spanish white clover and Portuguese lotus. You will be aware of the hybridisation programmes carried out in the ryegrasses that resulted in short-rotation ryegrass (Corkill, 1945), and shortly, we hope, in the release of long-rotation ryegrass (Corkill, 1957). Programmes are now being carried out at Grasslands in white clover, lotus, and fescue, crossing varieties well adapted to New Zealand conditions with introductions that have winter growth but are relatively poorer in other characteristics.

Second, breeding for improved efficiency of utilisation of water. Once we get over the problem of winter dormancy, in my opinion the greatest remaining limiting factor to high pasture production in much of New Zealand is lack of water. In what might be termed a good year the thoughts of a farmer turn from criticising the lack of production or persistence of his pasture to criticisms concerning lack of palatability or even stock sickness. In a normal New Zealand year, however, summer drought, although of short duration, is a real difficulty. If we could develop varieties of our main pasture species with improved utilisation of water, we would partially overcome one of the most important limiting factors in increasing production per acre. Differences between species, and limited indications of genetic differences within species, in the efficiency of dry matter production per unit of water used, have been reported by a number of workers (Myers, 1958), and point to this as one of the most fruitful areas of research. A great deal of study is needed on mechanisms of the absorption, translocation, and transpiration of water under varying morphological and physiological conditions. Perhaps we may find we need to select plants with characteristics limiting transpiration rather than plants with extensive root systems.

Third, breeding for quality. This is in its infancy and a great deal of biochemical and physiological work is required. This work must be associated with extensive plant-animal studies, so that, besides learning what makes a plant grow best, we may understand what is required for proper animal nutrition and what substances toxic to animals are found in plants.

This, of course, is not a new field; genetic differences in HCN content between white clover plants were reported a number of years ago (Corkill, 1942). The Plant Chemistry Division has more recently reported differences in iodine content (Johnson & Butler, 1957) between plants of both white clover and ryegrass that are certainly genetic in origin. Quite recently we have found at Palmerston North that individual plants of red clover differ significantly in the amount present of an antibiotic substance that is toxic to the facial eczema fungus ***Sporidesmium** bakeri*. We have also found that genetic differences exist between plants of perennial ryegrass in their ability to grow at different levels of phosphate and that genetic differences exist between plants of white clover in the type of anthocyanin pigment present.

Work is under way at Grasslands at present, in collaboration with Plant Chemistry Division, to study NO_3 content in single plants of a wide range of species and varieties of both grasses and clovers. Studies are being made on differences between species and varieties of a range of legumes in oestrogen content, in collaboration with Massey College. In our fescue breeding programme work is under way in collaboration with Plant Chemistry Division to determine the nature of the toxic substance present in tall fescue leaves and to see if some varieties do not have this substance.

We are only touching on the fringe of breeding for quality and welcome suggestions and seek every opportunity to collaborate with scientists who may be able to assist us.

Fourthly, breeding for competitive ability. A great deal of our selection work has been done on single spaced plants, but we are very aware of the fact that our bred varieties must finally perform well in a pasture subject to competition from other pasture species, together with the treading effect of the animal. There are a number of approaches to this problem. Fejer (1959) at Grasslands has found that there are genetic differences between single plants of ryegrass in their ability to produce under different levels of competition. But there are problems associated with selection based on competitive ability. Our present system of seed multiplication involves about five generations of increase from a small population of elite plants to the farmer. Therefore if we are to select for competitive factors, it may be important to consider a method of seed release that will shorten the number of generations from elite plants to farmer, because the type of competition in a seed crop may differ from that in a grazing pasture.

The Raw Material of Selection

The most important genetic characteristic of a population of plants is its variability, because without variability selection of improved varieties would be impossible. Variability may be natural or induced. Natural variability may be in the form of what may be termed a land race (Frankel, 1954) which has been established under natural selection. The raw material from which New Zealand-bred varieties of perennial ryegrass, cocksfoot, and white clover were selected is considered to be of this type. Or variation may be from an introduction. An introduction may of course possess sufficient good agronomic characteristics to be of value without modification, and bred varieties of Montgomery red clover, Italian ryegrass, and timothy have been selected from this type of raw material.

However, although introductions may not be of use as they are, they may possess certain excellent characteristics which can be transferred to varieties already adapted to New Zealand conditions; for example, Spanish white clover has excellent winter growth surpassing that of our present bred variety, but is poorer in summer growth and in type. We have a crossing programme to attempt to transfer the good characteristics of the Spanish variety to the New Zealand variety.

Induced variability is of three main types. First, recombination by hybridisation within species, between species, or between genera may produce new. types. Both short-rotation and long-rotation ryegrass have been selected from hybrid populations of a distinct type. At the intergeneric level Anderson at Grasslands has found occurring naturally and has also produced by deliberate crosses sterile hybrids between ryegrass and tall fescue. We have at present a large programme to try to induce fertility in this hybrid.

Second, the drug colchicine may be used to induce tetraploidy; that is, plants with double the usual number of chromosomes. In tetraploids, apart from a frequent increase in size of plant parts, there are greater opportunities for accumulating desirable genes and undesirable recessive genes take longer to segregate out. In Lotus *uliginosus* and in red clover we hope to turn out polyploid varieties for trial within the next few years. In a comparison between mown plots of diploid and tetraploid varieties of New Zealand *Lotus uliginosus* selected by myself at Grasslands and also between diploid and tetraploid varieties of late flowering Montgomery type red clover selected by Anderson at Grasslands, the following results were obtained. In both species the tetraploid (or 4n) variety has about a 12 per cent superiority over the diploid (or 2n) variety in total dry matter production. However, both tetraploids have more extended seasons of growth compared to the diploids, the 4n lotus has a 60 per cent superiority over the 2n in the spring, while the 4n red clover has a 32 per cent superiority over the 2n in the autumn. In both these species we have yet to carry out grazing trials and to complete studies on seed setting, which is generally poorer in 4n varieties than in 2n varieties, but results of this magnitude give us confidence to continue with the programmes.

Finally, radiations or chemicals may be used to induce specific mutational changes, alter chromosomal architecture, or break closegene linkages (Muller, 1954). It is generally agreed that in cross-fertilised plants sufficient variability can usually be found by collecting widely, and the use of radiations is not of advantage. There seem to be two exceptions to this; first, in breeding for disease resistance the disease organism acts as a very sensitive detector of any induced biochemical changes; second, in attempting to improve plants that set seed without fertilisation. *Paspalum* *dilatatum* is apomictic and there is likely to be too little variation to enable us to make sufficient improvement by selection. We hope shortly to irradiate paspalum seeds and grow the resulting plants in comparison with plants from untreated seeds to find out if we can induce worthwhile new variation and particularly if we can induce sexuality.

Breeding and Selection Methods

The methods developed independently by pasture plant breeders throughout the world have generally been of the type practised at the Grasslands Division. Elite plants selected from large populations of plants are progeny tested. A number of cycles of selection may be practised, especially in hybrid populations produced by crossing varieties or species, though selection within land races may not require this. Pasture plant breeders have sometimes dreamt of being able to utilise hybrid vigour in a similar fashion to that of maize breeders who produce hybrid corn by crossing lines developed after years of inbreeding. I would like to point out that the development of chemical substances such as FW450* that emasculate without other damage makes a hybrid corn approach a definite possibility in pasture plant breeding. Inbreeding, however, causes strong loss of vigour and great decrease in seed production in pasture plants, and we favour a mode of breeding termed "reciprocal recurrent selection" (Comstock et al., 1949) which could achieve the hybrid vigour of
However, there have been interesting developments in maize
hybrid corn without any inbreeding.
breeding in recent years; Lonnquist & McGill (19.56) in Nebraska have by recurrent selection .(a process hardly distinguishable from that used by Dr Corkill in producing short-rotation ryegrass) achieved in only the second selection cycle a close approach to the performance of the hybrid corn control. This method has the advantage of maintaining genetic diversity for future improvement work. I consider that in pasture plants the utilisation of hybrid vigour, though now a distinct possibility, may not be, in general, an advantage unless uniformity of morphology and performance simplify the application of mechanisation and of advanced fertiliser practice, as stated by Hutchinson (1958).

I would like to stress the time factor in plant improvement work of any type, 10 to 15 years often being required to turn out a new variety for the farmer. Breeders of cross-fertilised plants appear practically without exception to have followed a practice of selecting a relatively small number of elite plants in any generation and throwing away the remainder. This inevitably results in

* We are indebted to Ivon Watkins Limited for experimental supplies of this substance.

having finally eight or ten very elite plants that cannot be bettered without starting the whole programme again. Hutchinson (1959) has recently challenged this practice and suggested that better long-term progress will be made if selection is based on the elimination of the worst rather than the retention of a small elite in any generation. It would seem to me that these two very different types of selection procedure are not mutually exclusive, that selection of elite plants will usually be required for producing varieties for the farmer, and that Hutchinson's method may well help us to produce very different populations of plants within which we can select elite plants to produce a variety for the farmer.

In conclusion: First, I would like to stress the importance of precise definition of breeding objectives. Hutchinson (1958) reports that a survey of successful breeding projects carried out in recent years in East Africa shows clearly that those who made real advances have been those who had a precise and definite objective in their selection work. One plant breeder stated in reply to an inquiry "an improvement in any character would be welcome!" There is no record of any improvement in his material.

Second, I have spoken of the "raw material of selection", We must make more plant introductions from all over the world and cross them with New Zealand adapted varieties. The Mediterranean region in particular appears to be a key place from which to collect seed.

Thirdly, we must be alert to any better breeding methods that may be developed for other types of plants and must not hesitate to experiment ourselves.

Finally, Professor W. M. Myers titled his Presidential address to the American Society of Agronomy in 1958 "Unfinished Business" and cited much promising and exciting work of the last quarter of a century that has not yet led to improved varieties reaching the farmer.

We too have much unfinished business.

Acknowledgments

I wish to acknowledge the assistance of members of the Plant Breeding Section at Grasslands Division who have, by discussion, contributed to this paper and to Mr L. B. Anderson for permission to use unpublished data on red clover tetraploids.

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DISCUSSION

Q. (J. 0. H. Tripp): Has the winter growth of Spanish white clover been tried in Southland or Otago?

A. Yes. Comparisons between N.Z. white clover, Spanish white clover and hybrids between them have been made at the Grasslands Division substation at Gore. The growth of the hybrids is far better than that of the N.Z., which is better than that of the Spanish.

Q. (Walker): Can a tall fescue with non-toxic qualities be bred for planting on drain banks?

A. On our present information, we think so.

Q. (P. B. Lynch): Will Dr Barclay please comment on breeding for disease and insect resistance?

A. These are certainly important objectives. We hope this work will gain momentum with the establishment shortly at Grasslands Division of a section of Plant Diseases Division.

Comment (Dr L. Corkill): Only partial success followed breeding for resistance to blind seed disease in ryegrass.

Q. (W. A. Jacques): What are the factors for selection for better water utilisation in plants?

A. The physiological basis must be determined first whether it be lessened transpiration or more efficient root absorption or other factors.

Q. (Graham): What methods of hybridising could be used in pasture plants to produce results akin to those achieved in hybrid maize ?

A. In some circumstances reciprocal recurrent selection might be indicated.