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The Future of Grassland Research in New Zealand

J. MELVILLE, Director, Grasslands Division, Palmerston North.

WITH the knowledge that the results of current investigations may lead to entirely new paths of progress within months and even within weeks, no worker or administrator likes to be asked to provide a blueprint for scientific advances in his own field over an indefinite future period. The situation is not made any easier so far as I am concerned by the lengthy and doubtfully intelligible paper on pasture quality which I presented at the last Conference of this Society. The sole purpose of that paper was to indicate some of the more obvious gaps in our knowledge of pastures, and by implication to show the direction in which investigations should be pursued. It would be profitless to traverse that ground again and I propose to deal with quite other issues in this forecast of the tasks which face the investigators of the future.

On a number of previous occasions I have outlined the way in which the grass crop, particularly under New Zealand conditions, differs from all other cultivated crops whether they be for food, forage, or industrial purposes. Wheat, chou-moellier or soybeans, potatoes, lupins or cotton are invariably grown in pure stand, i.e., within the crop boundary the aim of the farmer is to exclude all plants other than the desired species and variety. Moreover, the purpose in growing these crops is to harvest the greatest amount of food, forage or industrial product per unit of area and per unit of time, the only proviso being that quantity without quality is a decreasingly profitable investment. Scientific workers whose disciplines impinge directly or indirectly on plant growth use only these criteria in assessing the value of a particular treatment or procedure.

Superficially the aim of the pastoral farmer is also to grow the maximum amount of plant product per unit of area and of time, but there are certain important points of difference. Within any one field he grows not one species or variety, but an association whose constituent species rise and fall in importance according to the season. The choice of species is made not only on inherent capacity to produce large yields of herbage, but also on the ability of the association as a whole to provide food for grazing animals month by month. Further, there is the paradoxical situation that the key to high pasture production under New Zealand conditions lies in plants of only moderate productive and competitive capacity: the clovers are included primarily to satisfy the nitrogen demands made by the highly productive grasses of the association.

Two more important points arise from the fact that pastures are associations of plants. Firstly, pastures are grown from North Cape to the Bluff and from about 3,500ft. down to sea level. This diversity of environment leads to markedly different associations, and the resultant harvest of pasture herbage therefore varies greatly in botanical and chemical composition. It does not possess the uniformity and homogeneity of wheat grain or cotton fibre. Secondly, the requirement of grazing animals demand that the harvest be taken on every day of the year. This results, at one end of the pasture management scale, in a continuous harvesting process (set stocking), and at the other end in a succession of harvests at monthly intervals or closer (rotational grazing), with all kinds of permutations and combinations of these extremes. And it must be emphasised that just as soil and climate are determining factors on types of association over the country as a whole, so the composition of any one pasture is the resultant not only of the species sown by the farmer but of the management he imposes.

The high mineral requirements of productive pastures are met, except for the establishment stage, by fertilisation exclusively at the soil surface. Moreover, a clear distinction must be made between applications which are made artificially by mechanical means and those which result from the excretory processes of grazing animals. Exactly the same elements are involved in each case, although naturally the farmer does not apply a nutrient which is available in ample quantity in the soil. The distinction lies in the form in which the elements exist in fertiliser and excreta respectively, and in the evenness of mechanical distribution as compared with patchiness and high local concentrations inherent in the voiding of dung and urine.

Mineral nutrition must, however, be kept in its proper perspective. Of the dry tissue of a plant only about 10% comes in through the roots; the remaining 90% is derived from the air through the leaves which, quantitatively, are of very much greater importance as nutritional organs than are roots. Here another major point of difference from other crops arises. In no other crop is continuous or repeated defoliation an essential concomitant of management: on the contrary it is standard practice with other crops to produce and maintain maximum leaf surface. The very delicate balance which must be maintained between animal and plant requirements for leaves poses quite unique problems.

The final point I want to make in this introduction is that the grazing animal has an effect other than as a manurial and defoliative agent. Pasture plants are continuously being trodden by animals ranging in weight from a few pounds to over half a ton, with loadings up to many pounds per square inch of hoof surface. The effect on plant growth and on soil consolidation is never negligible; certain soil types and at certain seasons it is the major limiting factor in carrying capacity.

In this brief introduction I have been concerned with certain characteristics which are peculiar to the grass crop and since they form the framework of the subsequent discussion, a summary would be in order: The pasture herbage consumed by our sheep and cattle populations is derived from a wide variety of plant association; the botanical composition of each association is determined by the species sown, by climate, by soil type, and by grazing management; nitrogen and essential minerals are applied solely at the soil surface and derive from two sources, mechanically spread fertilizers and animal excreta; there is continuous competition between the two members of the pasture—animal complex for leaves, which are the sole food of the animal and the main nutritional organs of the plant; and the pasture association is subjected to continuous treading by the animal.

In using these points as a background to the rest of this paper I do not want to imply that the problems facing the pasture worker are only those which do not apply to the growth of other species. But I do want to stress that in my view they form a set of postulates which are fundamental to the future of research in grasslands; I suspect that a great deal of unprofitable investigation, both here and overseas, has been carried out in the past simply because the research worker has not kept these elementary facts continuously in mind. One conclusion in particular stands out very obviously: any investigation of pasture productivity in which the research worker does not give full weight to the grazing animal as a determining component of the environment is certain to be of onlv limited success and applicability.

Taking the points in order, let us look first at the wide variety of pasture associations which exist in New Zealand and consider, not the degree to which carrying capacity can be increased by the full utilisation of existing species and strains, but the investigational work which is still required for particular habitats or for particular purposes. To this end, a division of our pastoral land into ploughable and non-ploughable, with subdivision into arid or semi-arid and humid, would be appropriate. On ploughable land the questions are: in what features are our present associations of pedigree pasture plants deficient; can those deficiencies be remedied by changes in one or other of our present range or should we go to entirely new species in the hope of overcoming them. It appears to us at Grasslands that the background to these questions may be summarised as follows: In pedigree white clover we have a plant with a higher capacity for nitrogen fixation than any other temperate-climate pasture legume. It seems unlikely that any other species will replace it on all ploughable land with adequate moisture supply, while its usefulness will be further extended through the recent introduction of a plant of Spanish origin with considerably greater capacity for growth at low temperatures. With the two strains of red clover (Montgomery and Broad) and sub-clover for ploughable lands which cannot be irrigated, the leguminous component of the sward appears well catered for.

The present range of pedigree grasses includes perennial, short rotation and Italian ryegrasses, cocksfoot and timothy while a fourth ryegrass with characteristics intermediate between short rotation and perennial is at an early stage of development. The three genera **Lolium, Dactylis** and **Phleum,** have over many years of trial and error in a wide range of temperate regions, established themselves as the most productive and flexible of the pasture grasses. The improvement made through plant breeding have further extended their spheres of usefulness.

It is conceivable, however, that further improvements may be brought about by the incorporation into these species of valuable genes from other species or even other genera, but the possibility of interspecific and intergeneric hybridisation in pasture plants has as yet not been explored. Current work by Anderson on hybrids between **Lolium** and **Festuca,** which may make possible the introduction into the former of quite new characters, would, if successful, appreciably extend the range and usefulness of ryegrass.

The search for new pasture species and the modification of existing ones is of particular importance in the sub-tropical areas of Northland and the northern section of the Auckland province., where the two species paspalum and kikuyu thrive. In this transition zone between temperate and tropical climates, between a much investigated grassland environment and one which is at an embryonic stage of investigation and development, a plant introduction, selection and breeding programme would certainly pay handsome dividends. Emphasis would of course be laid not on the traditional species of Northwestern Europe but on those of regions much nearer to the Equator, while the work would be greatly facilitated by a more precise assessment of the climate of our sub-tropical regions.

With the range of grasses and clovers already mentioned all kinds of changes can be rung on pasture associations on ploughable country to cope with particular climatic patterns or animal demands. The hill country farmer, through his inability to cultivate the land and prepare a seed bed, cannot transform one association into a quite different one in a matter of months as can be done by his lowlands confrere. Nevertheless the initial problem in the improvement of our wetter hill country pasture associations is already largely solved: progressive farmers and research workers have successfully introduced clovers by oversowing, while Suckling's work at Te Awa and elsewhere in the North Island makes possible firm recommendations for pre- and post-sowing management and for thickening up an initially sparse clover stand. I am convinced that the way is clear for the removal of the major limiting factor to pasture production, viz lack of nitrogen, on all our wetter hill country and on a large part of our drier hill country.

With the removal of that limitation, however, the next problem which has not been solved is that of introducing those grasses which can make better use of an adequate nitrogen supply. Suckling's earlier attempts to introduce better grass species by oversowing were almost completely unsuccessful. No part of his current research programme has higher priority than a study of the environmental factors which govern all stages of development of grasses in an established association from inbibition of the seed to onset of tillering.

The semi-arid to arid hill country of the South Island is the Cinderella of the grasslands of New Zealand and I have to confess to a complete lack of first hand knowledge of its problems. The evidence at present available indicates that much remains to be learnt of the plants which will grow under those sets of environmental conditions, and still more about the knitting of those plants into the most productive association. With the growing collection of meteorological data and with the plant introduction and selection which has been done in other regions of the world with similar climatic patterns, there would appear to be no inherent difficulties in gathering this information. Then it should be possible to answer such outstanding questions as the necessity for preserving the native tussock as the dominant species in the association, possible replacement by more productive species, the compatibility of tussock or its replacement with some pasture legume and so on.

Thus far I have dealt with induced changes in pasture associations aimed at increasing the yield and spread of production of herbage, and it is implicit in the argument that the proportion of low-producing or undesirable species will thereby be reduced. This is only partly true since weed invasion occurs even in the most productive associations, and the problems become more acute as productivity decreases. Spectacularly successful agents for weed eradication have appeared during the past decade, but they do not represent the final answer. With many weed species these new techniques merely emphasise our lack of knowledge of their growth characteristics, and of their mechanisms of survival through long periods of adverse conditions. In this connection no discovery could be of greater importance than the breaking of dormancy of buried seeds.

So much for the investigations which are needed for the improvement of our wide variety of pasture associations. Let us look next at the problems of their nitrogenous and mineral nutrition, which is achieved by additions solely at the soil surface. Some obvious questions immediately arise: Are pasture plant roots concentrated near the surface to meet this situation and what proportion of their mineral intake comes through the surface roots? Are we justified in assessing soil nutrient levels by sampling at 0in., 3in., 6in. and so on? Should not more attention be paid to the top inch and subdivisions thereof? What are the underlying mechanisms in transfer of nutrient ions to lower levels in the soil profile? What proportion of the applied minerals, whether of artificial or animal origin, is absorbed through aerial parts of the plants—leaves, stems and stolons? Finally, what is the effect of drought on the one hand, and of excessive moisture combined with animal treading on the other, on the uptake of minerals from the surface layer.

Application at the soil surface is of particular interest in regard to phosphatic nutrition. At the last Conference of this Society considerable discussion occurred on the desirable levels of phosphatic topdressing on high production dairy pastures, and the majority of contributors were, I think, dissatisfied with the evidence for continued high applications. In view of the relatively high immobility of phosphate a study of phosphate distribution in the top inch of the soil profile under heavily topdressed pastures might produce considerable dividends.

The study of the animal as a fertilising agent is a fascinating but virtually untouched field. Doak's studies on the sequence of changes in plant and soil within a urine patch served both to outline the problem so far as nitrogenous compounds are concerned, and to show how rapid and how far-reaching these changes are. But his results posed far more questions than they answered. Although he outlined the ways in which nitrogen may be lost from the urine patch much more information is required on the effect of soil moisture, soil temperature, and soil type on the range of losses which may be expected. What is the effect on other bases of the sudden release of high quantities of ammonium ion? In particular what is the effect on potassium ion which is applied within the patch at levels of the same order as nitrogen? What is the fate of the minor nitrogenous constituents of urine—glycine, allantoin and the like—and to what extent are they directly utilised by plants? What is the effect on plant metabolism of high dosages of nitrogen. These are only a few of the long list of unanswered questions which should be asked about urine as a fertiliser.

Dung, which contains virtually all the calcium and phosphorus excreted by the animal, is of equal importance, and we are equally ignorant of the ways in which its nutrient elements are re-introduced into the soil-plant-animal cycle. What are the mechanisms involved in its rapid disappearance, particularly in rotationally-grazed pastures? What part is played by both macro- and micro-organisms first in its incorporation into the soil, and secondly in transforming its essential elements into available form? It would be an impossible task to investigate the combinations in which the various elements occur in dung, but a closer study of phosphate compounds would certainly be profitable. Again, these are only some of the questions to which answers are required.

And even when we get the answers there still remains the wider problem of applying that knowledge to the multiplicity of management systems which are met in the field. For instance, the lack of productive and palatable plants in hill country pastures, together with the grazing and camping patterns of sheep and cattle, has led to large fertility differences within short distances. I feel sure that better associations combined with improved soil nutrient levels will result in more even grazing and hence in a marked reduction in these differences.

In concluding this abbreviated recital of problems relating to the mineral nutrition of pasture plants, it cannot be too strongly emphasised that the animal is the most important source of surface applied nitrogen and minerals. Topdressing of pastures should be considered only in terms of remedying deficiencies and making good the losses in the cycle through soil, plant and animal of each of the essential elements.

Next I should like to discuss what I described earlier as the balance which must be maintained between animal and plant requirements for leaves. Much information has accumulated both in New Zealand and overseas, on the effects of severity and frequency of defoliation in changing the botanical composition of pasture associations, and this has resulted in turn in a fairly clear picture of the reaction of our major pasture species to different defoliative treatments.

But the information is not nearly precise enough for present and future purposes and at last year's Conference Mitchell reported on a different approach to the same problem. He grew individual plants of certain important species and determined the effect of defoliation at different light and temperature levels. The implication of this work and the direction in which it is being extended can best be appreciated by reference to his paper in the Proceedings of that Conference. I would merely like to add that in my view, research workers in New Zealand have been too much concerned with changing the root environment; too little attention has been paid in the past to the effect of variations in the leaf environment.

But there is another aspect of the problem inherent in the continuous or periodic defoliation of pasture plants. Defoliation results in a reduction of the plant's photosynthetic capacity or, in other words, defoliated plants are limited in growth by a primary carbon deficiency. Hence the problem of defoliation can be studied only in relation to all the other aspects of plant growth and productivity. Some of the environmental aspects have already been discussed during the past ten minutes, but there is also a genetic aspect of equal importance and certainly of equal complexity. Fejer is studying the heritability not so much of total production (which Corkill has been using for years in his plant breeding programme) as of the components which make up total yields. These include tiller density, tiller weight, leaf size and rate of increment and he is trying to put a heritability figure on these components.

In this discussion of problems I have deliberately omitted those relating to pasture quality as it affects animal health and production, and there just is not sufficient time even to to summarise them. When and if you subsequently read this paper I would ask that you do so in conjunction with that presented last year. No problem which I have touched on this afternoon is of greater urgency than those of the pasture-animal complex.

But even with that ommission I realise that my treatment of the problems of the future has been sketchy in the extreme. I have said nothing about the measurement and control of soil moisture levels, or of the problems which are peculiar to establishing pastures, of the different mineral requirments of the individual plants in a pasture association, or of the highly important one of the effect of pastures on soil fertility. What I have tried to do is to fill in some of the earlier framework, and to show, at least by implication, the technical and intellectual difficulty of the tasks which lie ahead.

Turning now to certain organisational aspects of the future, what I am about to say was not written from the narrow point of view of Grasslands Division, D.S.I.R. The problems which have been outlined or mentioned, with their numerous ramifications, will be solved not only by that Division, but also in greater or lesser degree by Soil Bureau, Soil Research Station, Ruakura, Wallaceville, Botany Division, the Agricultural Colleges and Crop Research Division, with Dominion Physical Laboratory, Plant Diseases Division, Applied Mathematics Laboratory, Animal Ecology Section and others contributing specialised skills and backgrounds through the Divisions directly concerned. This list is given, not to comment on the organisational and geographical fragmentation of agricultural research and its effect on future progress, but to stress that the comments which follow are applicable to all institutions which are concerned with investigating any of the many facets of the soil—pasture—animal complex.

I do not believe that the work needed to solve any one of the indicated problems can be done other than at a major research institution. Certain applications must be of course made in regions with peculiarities of climate or soil, but even here only indeterminate results can be expected unless the work is done on a properly equipped and staffed substation. In our experience the minimum requirement is one professional officer, three or four good technicians, and the requisite farm staff. Except in extremely limited fields of investigation, and those exclusively of an applied nature, there is no place in this scheme of things for the experimental and/or demonstration farm with at best a farm manager, one or two farm hands and a technician. I realise that this is contrary to accepted practice in this country, but the statement is the logical outcome of my previous conclusion that any investigation of pasture productivity in which the research worker does not give full weight to the grazing animal as a determining component of the environment is certain to be of only limited success and applicability. If you accept the one, then I feel that you must also accept the other, and I would remind those who disagree of the discussion which followed Ward's paper at the last conference.

But if I hold decided views on the physical facilities which are necessary for a proper attack on grasslands problems I hold even stronger ones on the people who will investigate them. In their solution, investigations at all levels of research effort, from the most fundamental to the purely applied will be required and men of ability and integrity are needed at all levels. But from what I have already said you will appreciate that I am particularly concerned here with the fundamental type of investigation, and for two reasons. Firstly I am convinced that New Zealand has not in the past given enough attention to fundamentals. Secondly I am equally convinced that much research effort has been wasted and is being wasted because we are prone to investigate symptoms and not the underlying causes.

Our real problems, the basic problems which I have already outlined, do not lie in plant, animal or soil husbandry. They are problems in chemistry (with particular emphasis on biochemistry), physiology and genetics which in turn are making increasing demands on physics and mathematics. I am sure they will not be solved by a process which has happened too often in the past, viz., the recognition of a problem in the field, the recruitment of an officer, (frequently one straight from University) whose background seems to fit the case, the provision of such facilities as the administrator deems fit, and an attitude of patient resignation while a solution is awaited. The problems I am considering are very complex ones and they lie primarily in the domain of the pure scientific disciplines. It follows that they will be solved only by men of real intellectual ability and technical skill, who are trained in one or other of those disciplines (and training must include post graduate study at the highest level available in the world). There is no graduate of the University of New Zealand in any of the five disciplines already mentioned who could not find tasks in the field of agricultural science which would tax his capacity to the limit.

The record of recruitment during the postwar period to our major research institutions in the fields under discussion would indicate that the great majority of our scientific administrators are not of this opinion. I have recently been delving into two sets of tomes, the Public Service Classification Lists and the Calendars of the University of New Zealand for the past seven years, in an attempt to discover how many Senior Scholars, 1851 Exhibitioners, and Postgraduate Scholars in Science, in the fields of Chemistry, Botany and Zoology are serving, or being trained to serve, our primary industry. The answer is, lamentably few. I know that not all the bright brains are to be found among scholarship winners but I am old fashioned enough to believe that a high proportion will be found there. Why then are so few of the best brains we produce working on the problems which so urgently require solution. It is no use putting the whole blame on the science faculties of the University of New Zealand, although I cannot help being critical of the lack of appreciation by University staff members of the real scientific problems of the country. A proportion must be laid on our shoulders —and here I am speaking of the men in whose hands the responsibility for recruitment lies. How many of us have first hand knowledge of the 3rd, 4th and 5th year students at both University and Agricultural Colleges? What efforts are we making to tie up the really bright youngsters and to offer them the prospects of difficult but highly rewarding scientific careers? - What efforts are we making to see that our institutions justify the prefix "scientific" and not "technological."

Of one thing I am positive. Unless we recognise as a major responsibility the recruitment and postgraduate training of our brightest young men, unless we achieve and maintain a better balance between the really first class men and the others on our respective staffs, then the progress of grasslands research will be correspondingly impeded.

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