
FERTILITY REQUIREMENTS OF PASTURES AND THEIR DIAGNOSIS

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The basic aim in an efficient system of pastoral farming must be the highest possible sustained yields of animal products consistent with the maintenance and improvement of soil fertility. This involves the maximum production of dry matter of the right quality. This paper does not deal exhaustively with quality, but it is necessary to remind ourselves that quantity and quality are not necessarily highly correlated. Both yield and quality of dry matter depend on the soil, climate, **herbage** species and strains, stock and pasture management and fertiliser applications.

On the question of quality, Melville has stated that **herbage** must provide

- (1) adequate protein and carbohydrates,
- (2) those minerals and accessory food substances essential to animal health, in a correct state of balance, and
- (3) no potentially harmful compounds at a level which causes animal disorders or a decline in production.

Unfortunately we know more about the nutritional requirements of plants than about the requirements of animals eating those plants. We can arrest all land development and the improvement of **herbage** yields until research tells us just what animals need, or we can improve **herbage** production and try to solve animal disorders as they arise. As it is now possible to diagnose and treat many animal disorders arising from impaired quality of **herbage**, there is no doubt in my mind that we must proceed with increasing **herbage** production. With our increasing knowledge, possible stock troubles on certain soil types can often be anticipated and remedial measures applied; failing that, any fresh problems of stock health that may follow increased **herbage** production will have to be tackled piecemeal, and this of course is no different from the situation facing us at present. As the gaps in our knowledge are closed, we should be able to modify and control not only the quantity of **herbage** produced, but also its quality.

Most of the factors influencing soil fertility can be classified as biological, physical, or chemical. This paper deals primarily with chemical factors, but it is worth noting that physical problems associated with soil structure are not nearly so serious in pastoral farming systems as in intensive arable cropping. As our knowledge of plant requirements has increased, we have been able to increase crop and **herbage** production by such empirical means as soil analysis, plant analysis, analysis of animal organs, visual diagnosis

of deficiency symptoms, and field experiments. It is remarkable how much progress has been made by people knowing little about soils and their formation. The success of the empirical approach has been a major factor retarding the proper scientific study of soils. A thorough knowledge of the properties of different soils and how they must be modified to meet our requirements is essential for a more scientific use of soils. In New Zealand we are fortunate in that we have accumulated and are accumulating at a faster rate more detailed basic knowledge of our soils than possibly any other country. This is perhaps to be expected in a country whose soils are the source of most of its material wealth. Even so, these fundamental studies of soils have so far mainly given a satisfactory explanation for what we have already discovered empirically, but increasingly they can be expected to guide and influence our progress in solving problems of soil fertility. I intend to state what I consider the basic principles underlying herbage production in New Zealand insofar as nutrients are concerned and then consider the assessment of the nutrient deficiencies and requirements of various soils by empirical methods and from more basic knowledge.

Pasture Productivity and Legumes

In New Zealand it is not necessary to stress the key position of nitrogen in herbage production. While most farmers in Britain make inadequate use of either nitrogen fertilisers or legumes in their pastures, we are fortunate here that on the ground of costs we must depend on nitrogen-fixation by legumes, principally white clover. This simplifies our approach and most farmers are aware that the basic principle underlying pasture production is the correction of all the factors limiting the establishment and growth of clovers. Paradoxically this dependence on legumes as a source of nitrogen means that there will be a deficiency of nitrogen unless all deficiencies except nitrogen are corrected. We cannot, therefore, as in many other countries, apply nitrogen fertilisers and then run into deficiencies of one or more other nutrients. If we are to get enough nitrogen we must first correct deficiencies of P, K, S, Mg, Ca, Mo, Cu, Mn, B, Fe, Zn, Cl, and Co, and also ensure nodulation of legumes with effective *rhizobia*. Assuming correct management, adequate nitrogen will eventually be forthcoming for associated grasses from overground and underground transfer of nitrogen from clovers and by enhanced mineralisation of nitrogen from accumulating organic matter. As clovers appear to be much more sensitive than most grasses to deficiencies of all soil nutrients except combined nitrogen, the application of nutrients to maintain vigorous clover growth will automatically meet the needs of

grasses for those nutrients; indeed a growing risk is the luxury consumption of some elements by the grasses with possible consequences for animal health.

Our Increasing Knowledge of New Zealand Soils

Taylor and his colleagues of the Soil Bureau have provided us with a satisfying genetic classification of our soils which is promoting and meeting the test of increased knowledge. There is a growing understanding of the influence of the soil-forming factors and processes on the quantities and nature of the clay minerals and of their important influence on soil fertility. The nature, forms, and availability of soil phosphorus are becoming better understood. A fairly comprehensive picture of our soils is slowly emerging and various nutrient deficiencies can be explained and anticipated. Some of these aspects were discussed at a recent meeting of the British Grassland Society in London (Walker, 1960). Even when we have a complete account of our soils and have a thorough understanding of their properties, there will still be a need for empirical methods in diagnosing fertility problems, and at present any or all of the following may be used:

- (1) Field experiments
- (2) Routine soil tests
- (3) Analysis of plant and animal organs
- (4) Visual diagnosis of disorders in plants and animals.

Field Experiments

These have been and always will be an important feature in the diagnosis of deficiencies. They are an essential adjunct to assist in the evaluation of other techniques; for example, soil tests may be quite misleading on some soils and field experiments will locate these abnormal soils for which new methods of analysis must be devised. I am perfectly happy with straight clipping trials, particularly if legumes are separated from other components of the herbage, for establishing the nature of deficiencies and even for indicating approximate quantities and forms of nutrients needed to give maximum production, at least initially. For fixing subsequent rates of fertiliser dressings and frequency of application more experiments are needed that bring in the grazing animal'; but as such experiments must include differential manuring and stocking rates, they will be large and complex, and we may have to depend for a long time on such techniques as "mowings and clippings returned", (Lynch 1947).

With improved knowledge fewer errors are made in interpreting the results of field experiments. Today no one would use superphosphate to examine phosphorus responses, because of the possibility of major effects from the sulphur in the gypsum. For the

same reason it is unwise to use the sulphates of the trace elements when testing the effects of the latter on pasture production. While there is still a place for simple interaction trials involving only two or three nutrients, there is an increasing need for the 2nd half-replicate confounded block experiments used successfully by Daring *et al.* (1960) where the effects and interactions of seven nutrients at two rates were examined. Such trials are essential in zones of strong weathering and strong leaching where multiple deficiencies are likely to be common.

Field experiments are still the only reliable way of assessing deficiencies of some elements such as sulphur where atmospheric returns are important, and for studying lime-molybdenum interactions and problems associated with rhizobia.

Routine Soil Tests

Whenever routine soil testing is carried out the determinations are usually restricted to assessing the pH and levels of available P, K, and Ca. As stated above, they are of most value where field experiments have been carried out on the same soil types which are to be analysed. Some slight progress has been made in assessing the nitrogen status of soils for arable cropping, but the need is not urgent in New Zealand. There is no good reason why Mg could not be added to the list with more experience, although the distinct differences between grasses and legumes in uptake of Mg will make interpretation difficult, particularly where hypomagnesaemia may be involved. Not many experienced soil scientists would be prepared to use routine soil testing as a basis for diagnosing deficiencies of trace elements in the present state of our knowledge. I have more confidence than many people in the value of soil tests, provided they are evaluated against the results of field experiments.

Visual Diagnosis of Disorders in Plants and Animals

When a deficiency is sufficiently severe, specific symptoms are shown by both plants and animals and with experience may be diagnosed by eye. The symptoms shown by legumes are usually more easily detected than those of grasses, and several of the trace element as well as macro-nutrient deficiencies can be diagnosed by the appearance of legumes. Complications arise where there are multiple deficiencies or threshold deficiencies, when symptoms may be masked or less evident. Responses to application of deficient nutrients may occur even when symptoms are absent, and it can be assumed that deficiencies are acute if symptoms are pronounced. It is not always correct to assume that the real cause of a

deficiency is due to a soil deficiency of the element in question. Magnesium deficiency in plants may sometimes be due to uptake of excess K rather than an absolute deficiency of Mg; similarly Cu deficiency in animals may be caused by excessive intake of MO. I have even see Fe deficiency in oats on an extremely acid soil, which is a most anomalous situation, as it normally occurs on alkaline soils. It was probably due to very high uptake of Mn.

Analysis of Plant and Animal Organs

These analyses are most important for diagnostic work and particularly for confirming conclusions reached by other means. By analysing the various species from fertiliser trials and plants showing deficiency symptoms, it is possible by paying sufficient attention to stage of growth, seasonal effects, and others to establish desirable levels of elements. Deficiencies can be expected where plants or selected organs contain less than those levels. Evidence of luxury consumption of certain elements is often valuable, and in problems of soil fertility the more plant analyses that can be carried out the more complete will be the picture. Trace element and other obscure problems are often best attacked by such analyses. In one particular trial (Walker *et al.* 1955) on a moderately acid soil,, we obtained **marked** responses to double superphosphate as expected, but a depression from ordinary **super**-phosphate and a response to molybdenised superphosphate. These puzzling effects were explained by plant analysis, because gypsum increased Mn uptake by clovers to the point of toxicity, which was corrected in the plant by MO, or in the soil by prior liming to lower the level of exchangeable Mn.

Plant analysis, too, brings out differences in the element contents of species and strains and is now being used by plant breeders. It is well known, for instance, that the Ca and Mg levels of clovers are usually rather higher than in grasses. In the case of Mg there is little doubt that the seriously increasing incidence of **hypo**-magnesaemia in Holland and Britain is associated in many cases with increased use of N and K **fertilisers**. Nitrogen suppresses clovers and promotes the growth of grass of lower Mg content; in such cases heavy applications of K cause luxury consumption of K by the grasses, so that the animal ingests less Mg and more K. The incidence is less in New Zealand because of our reliance on the legume, and where K stimulates clover growth it may even increase Mg intake. Where soils are deficient in both K and Mg there is a risk of inducing hypomagnesaemia from applying K, particularly during phases of grass dominance, but the solution is not to stop using K, but to use Mg as well.

While there are still many puzzling problems, our knowledge today is such that if there were enough scientists and money, there is virtually no problem of soil fertility concerning pasture production that could not be solved. This statement cannot yet be extended to include animal production, which after all is vital to us, but an increasing number of animal problems are being explained. In the case of such an unexpected finding as the relationship between vitamin E metabolism and selenium deficiency, it is clear that some of these complex problems will be solved only by basic biochemical research. Other unsolved animal disorders are not likely to be answered by blunderbuss applications of various mineral mixtures, although where a farmer has a problem which cannot at present be solved I am sympathetic but sceptical about their use.

The Problems Following Diagnosis of Deficiencies

Although we have reached the stage where no farmer need be long in doubt as to what fertilisers he needs for increasing pasture production, this is a far cry from being able to advise him on the quantities, forms, and times of application to give him maximum net returns. As returns get less and costs increase (although fertiliser costs have remained remarkably steady or have even decreased in the case of potash), these problems need to be answered. There are probably few farmers applying too much fertiliser for it to be unprofitable, but we cannot expect farmers to increase their use of fertilisers unless we can give them much better guidance. I consider this to be one of the major problems facing soil scientists and agrostologists in the next 10 years.

REFERENCES

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Lynch, P. B., 1947: N.Z. J. Sci. Tech. A28:385.
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DISCUSSION

- Q. (Pantall): Would Professor Walker comment on the most economic forms of magnesium to use?
A. The forms used can be dolomitic limestone, magnesium carbonate, or serpentine super. I have no idea which material is the cheapest, that would depend on local conditions. Dr Doak has shown that serpentine superphosphate can maintain magnesium levels in the soil. In Britain magnesium carbonate or dolomite is used at heavy rates; these materials are cheap there. Epsom salts is used there in glasshouses.

Comment (D. E. **Hogg**): At Rotorua, dolomite and serpentine super have been applied at equivalent rates of magnesium and for the first six months the magnesium uptake from the serpentine super area has been greater. Also soils where hypomagnesaemia has occurred have been analysed on many occasions and have not shown less magnesium than other soils.

Q. (G. Jensen): Would Mr Elliott give figures for potash application?

A. (I. L. Elliott): Farmers in this district are not even keeping pace with the outgoings of potash in hay, milk, etc., and at least twice the quantities of potash should be used.

Comment (**H. Gibbs**): The pumice soils have a greater capacity for holding organic matter and therefore nitrogen than the greywacke series described by Professor Walker and it is for this reason that it has taken so long to reach the desirable stage of high nitrogen supply to grasses.

Comment (**Allo**): I agree with the advice given to Mr Jensen; soil tests show that he has potash deficiency on his farm. The pastures seen on the field day were not the best; they were chosen to provoke discussion and draw attention to K deficiency. Potash was used initially for big clover build up, then came the bloat stage. Bloat is experienced on many farms in the district where potash has never been used.

Comment (I. L. Elliott): You must put on plenty of potash to get through the clover stage.