THE PREDICTION OF THE NUTRIENT REQUIREMENTS OF PASTURE

I. L. ELLIOTT, Superintendent, Rukuhia Soil Research Station

Up to the present we have been dependent for our knowledge of the nutrient requirements of New Zealand soils largely on the results of field trials established on classified soil types, At the same time there has been much laboratory examination both of soils and pastures in connection with these trials. Although the field trial has served us well in the past and will probably always be regarded as the final arbiter in deciding the presence or absence of nutrient deficiency, it must be admitted that it has some drawbacks.

The first of these is that, strictly, the results of the field trial are applicable only to conditions which are precisely the same as those which occur on the trial area itself. In practice we are inclined to argue that, provided trial sites are carefully picked, the results of the trial can automatically be translated as applying to the whole of the soil type on which it is located. The soil type must of necessity, however, contain within it a range of conditions, and must be subject to various influences. Some of these influences may be of such significance as to modify soil-type considerations to the extent that they dominate the whole picture. Under these conditions it would seem highly desirable to concentrate on the development of techniques which will enable us to delimit nutrient deficiencies on a paddock basis. The field trial is too cumbersome to enable this to be done, and the obvious approach would appear to be the use of some laboratory method.

The second shortcoming of the field trial is not so much a fault of the trial itself, but rather of the way it is used. Most of the field trial work on nutrient deficiencies, apart from that carried out on research stations, is conducted by Farm Advisory Officers of the Department of Agriculture. It is no secret that many more officers than are' at present employed could be used on purely straight advisory work and that few of them have adequate time to devote to experimental work. Many of the trials which are established fail to yield conclusive results and frequently this is the fault of the cooperating farmer and not the Farm Advisory Officer. But wherever the fault lies, it is, I feel, a fully justifiable conclusion that much valuable evidence is lost through lack of sufficiently frequent observation, particularly at critical times of the year which, incidentally, tend to coincide with the period of maximum activity in other fields of the advisory officer's duties. I would not like you to consider this discussion a criticism of the activities of Farm Advisory Officers. I consider it a criticism rather of the conditions under which they have been forced to work, and in spite of all this New Zealand has, I feel, been exceedingly well served, and the body of organised knowledge accumulated here compares more than favourably with that found in other countries.

In trials, particularly when investigations are being made on nutrients whose mode of action is through the nitrogen-fixing bacteria on the roots of clovers, significant effects may be observed for only a short time. The relatively large distances which must separate field trials (and the demands of other duties on the advisory officer's time) mean that frequently they must not be observed as often as would be justified.

It is not the purpose of this paper to advocate the substitution of other methods for the field trial, although this would be advantageous if it could be done, but rather to suggest an intensification in the methods which could, I believe, make our field trials more useful and more efficient.

Several techniques are available. I propose to examine these in sequence.

Soil Analysis

For the last 100 years at least it has been the dream of soil chemists to be able to predict the nutrient requirements of plants by analytical methods. To me, it is not a matter of amazement that they have largely failed; rather am I amazed at the extent to which they have succeeded in view of the extraordinarily complex field in which they have had to work. The real difficulty, of course, has been to find extractants which in the laboratory can be used to remove nutrients from the soil in the same way that the plant does, and to distinguish between that fraction of the element concerned which is available to the plant and that part which is not.

Soil analysis in New Zealand has a long history. In the early 1860s farmers were encouraged to send in bags of soil to the analyst to the Colonial Office, who was prepared to analyse it and to predict a suitable fertiliser regime. A fresh impetus was given to this work with the appointment of B. C. Aston in 1899, but again this method of determining nutrient requirements fell into discredit. Even though large numbers of analyses were carried out by various institutions, it wasn't until the establishment of the soil testing service of the Department of Agriculture in the early 1950s that soil testing began to become accepted by Advisory Officers and the farming community also as a reasonable means of gauging the fertiliser requirements of a soil.

It must, however, be freely admitted that the chemical method became possible only because of the large amount of background evidence which had been built up of well documented responses in the field, and with which it was possible to correlate the results of chemical analyses. And even now it must be equally freely admitted that soil analysis has its limitations and can sometimes result in misleading conclusions. Nevertheless it is true that it is a technique of extreme value and is capable of giving the right answer under conditions where no other method would be feasible.

Most of the predictions which so far have been possible have been in the field of the major elements-phosphorus, potassium, calcium, and magnesium-but much work has also been done on the development of methods which might be used in connection with other elements. On present indications useful methods are available for the determination of sulphur, molybdenum, and copper, but whether or not they will be put into use for the examination of soil samples on a routine basis depends on a number of factors which cannot be discussed here.

Plant Analysis

The analysis of plant tissues appears the ideal method of determining the capacity of the soil to release elements for plant growth. It could be argued that in this way the difficulty of selecting a suitable extractant would be avoided; because the plant had already provided the extractant and taken up the materials it required. There are, however, a number of extreme difficulties inherent in the method, particularly where one is concerned with predicting the nutrient requirements of a complex association of plants such as is encountered in a pasture. Thus plants will take up nutrients to a level not necessarily dependent on their needs, but dependent on the supply and form of that particular element in the soil. Thus it is possible to encounter' so-called luxury uptakes in herbage. Deficiency of a particular element is not absolute but will depend on the level of other plant nutrients present. For example, the amount of sulphur needed by the plant at high nitrogen levels is much greater than at low nitrogen levels. The whole business, then, is extremely complex and the big difficulty lies not in carrying out the analyses but in how to interpret them.

The development of the spectrographic section at Rukuhia under Mr J. E. Allan has revolutionised the possibilities in this field. It has made feasible the carrying out of an enormous number of plant-ash analyses, by which it has been possible for Mr K. J. McNaught to build up a set of reference data on plants growing under a range of nutrient conditions in the field and to establish criteria of deficiency, adequacy, and luxury. Even though over a quarter of a million analyses for a range of elements have been carried out, Mr McNaught himself would be the first to admit the limitations of the method and the difficulty of placing an accurate interpretation on results of analysis. Again, however, the method is undoubtedly most valuable and is of wide application. I would think that in few laboratories in the world has this amount of work on pasture plants been equalled.

Pot Trials

Pot trials as a diagnostic aid in determining the nutrient requirements of plants have also had a somewhat chequered career. Aston used pot trials for this purpose many years ago, and many others since have used the technique under specialised conditions. The man who takes a broad view of nutrient deficiency and insists that pasture requirements can only be worked out in the presence of pasture plants and grazing animals, is likely to be the most damning critic of pot trials.

I must admit that in the past I have held the view that pot trials constituted too artificial an approach to be worth considering as a diagnostic method, and I have been guilty of uttering most of the cliches commonly applied to this kind of work. Of recent years, however, I have seen so much value come from this work that I have no hesitation in recommending it as a most useful means of achieving our common goal of a more exact method of cataloguing our soils by nutrient deficiency. There are a number of reasons which I submit as being worth consideration.

Firstly, pot trials can be conducted in large numbers at some central location to which a number of soils can be brought. Full replication and daily observation on the growth of plants in pots can be made efficiently and easily without the need for costly travel. Because numbers of different soils can be examined at the same time, the method enables easy checks to be made between the behaviour of plants growing in one soil and those growing in other soils. Thus the method is particularly suited to the survey approach.

Use of the pot-trial technique makes possible extension of the growing period of the plant by the control of some environment factors. Thus effective work can be carried out even through winter and periods of drought.

One of the aspects of pot trial work which I feel is extremely important is that it permits the isolation of the elements in a mixed sward and allows observations to be made which, though quite clear in pots, may be difficult in the field. For instance, in the slide showing the effect of copper on the Te Kopuru sand, the non-copper-treated clovers could be passed over in a mixed pasture in the field as being perfectly healthy. The yield results of the pot trial, supported by analytical data from both soil and plant, show otherwise. There has perhaps been a tendency for us to say if the field trial hasn't revealed a response while pot trials and analyses have suggested that one could logically have been expected, that the field trial results must be wrong and that, by implication, the analytical and pot trial results must be right. I have less belief in this attitude than 1 used to have.

It must be admitted, however, that for some types of investigation of extreme importance pot trials are of little, if any, use. I don't think they are' of much value for the study of major elements, where the problem is really not one of whether they should be used (we already know or can find out about that by other means anyway) but principally what are economic maintenance rates.

Conducting pot trials is by no means as simple a technique as might be thought. All sorts of specialised problems, such as disease control, can very readily arise and mask the main effects of a treatment.

However, in spite of all these factors, pot trials have many advantages, and for some purposes constitute a most valuable diagnostic weapon. .

Other Laboratory Techniques

There are undoubtedly a number of laboratory approaches to the main problem of determining nutrient deficiency, but one I feel shows considerable possibilities, although promising early results still require vindication by field evidence.

For some time now Mr D. E. Hogg of the Rukuhia staff has been interested in the downward movement or leaching of various plant nutrients and has devised a technique by which he studies it. The procedure involves packing the soil into plastic cylinders in a device in which drainage from the column can be collected for analysis. Water is applied to the top of the soil and allowed to drain through. The amount of water applied roughly approximates four times the rainfall the soil would be exposed to in one month.

Now this procedure is again highly artificial and is a far cry from what can actually be expected to happen in the field, where both plants and animals are present to recover and recycle nutrients moving down the profile. It is probably true, therefore, that what happens when these columns are leached is probably of no absolute significance. But if these columns are used for comparative purposes, some interesting facts begin to emerge.

Thus in a series recently commenced at Rukuhia a number of soils was compared with the Horotiu sandy loam. After leaching, the percolates were examined for phosphorus, potassium, magnesium, and sulphur. For permission to present these hitherto unpublished data, I am greatly indebted to Mr Hogg.

Soil Type	Total of applied P leached %	Total of applied S leached %	lb Mg per acre expressed as dolomite	Total of applied K leached %
Horotiu sandy loam:				
Control			81	—
KCl + super.	Nil	2	128	10
Te Kopuru sand:				
Control			70	—
KCl + super.	15	94	166	48
Wharekohe silt loam:				
Control		—	114	—
KCl + super.	41	112	288	21
Te Anau brown loam:				
Control		—	17	—
KCl + super.	1	Nil	128	14
Galatea sand:				
Control	—	—	49	—
KCl + super.	1	82	161	66

The table shows quite clearly wide differences in the behaviour of the soil types to the standardised procedure of the leaching technique. Whereas the Horotiu sandy loam, Te Anau brown loam, and Galatea sand lost virtually no phosphate, two North Auckland soils (Te Kopuru sand and Wharekohe silt loam) certainly did. The story is even more dramatic with sulphur. Horotiu or Te Anau lost nothing, but Te Kopuru sand, Wharekohe, and Galatea sand lost virtually all the applied sulphur. The others results are self-evident from the table.

So though, as I have said, these results mean very little in absolute terms, they do reveal wide differences, and there is at least some evidence already to suggest that these differences are important in practice.

In the brief review that time has permitted me to give of methods of predicting nutrient requirements of pastures, I have tried to show that the well-tried and proved field-trial method can be reinforced by a number of other techniques.

It seems to me logical that if any method of approach is liable for one reason or another to yield unreliable results, it would be reasonable to combine a number 'of methods and see if the answer they give is the same as would be obtained from a trial conducted in the field.

This is precisely the approach being tried by the staff at Rukuhia with a number of pumice soils of the central North Island. If the technique proves reliable, it will be tried elsewhere and put into widespread use. This is, however, a taste of things to come; the suggested method has yet to be found reliable, Briefly the approach is as follows:

(1) Representative soil samples, typical of a particular soil type, are taken from a suitable site in the field.

(2) The sample is brought to Rukuhia and divided into a number of sub-samples. One of these is analysed for the complete range of important nutrients (both major and trace elements) ; another is set aside for examination by the leaching technique; and a third, if sulphur is implicated, is examined to determine the presence or absence of sulphur-decomposing organisms.

(3) The remainder of the sample is placed in boxes in the glasshouse in which clover for herbage ash analyses is grown.

(4) Field trials based on results from the examination of the sample by all the methods referred to above are designed. Results from these trials are compared with those from application of the other techniques.

There would seem to be many possible advantages from such an approach. Perhaps chief amongst them is the possibility of more effective calibration than at present of results of laboratory techniques as compared with field trials. Ultimately, it may prove possible, at least for some types of investigation, to rely entirely on predictions from laboratory studies and to discard the field trial. If this stage is ever reached, we will have much more flexible methods of predicting nutrient requirements than at present, and will be able to give farmers much more exact information on a paddock rather than a soil-type basis. This is the target we are aiming at; there seems a fair chance of hitting it if we use a multiple and not a single method of approach.

There is perhaps nothing very new in this paper, unless it is the discussion of the marshalling of all our techniques at the one time in a concentrated effort to yield a more detailed knowledge than we now possess of the nutrient deficiencies of New Zealand soils.

DISCUSSION

Q. (Professor Walker): Is Mr Elliott being too optimistic in suggesting that field trials could possibly be reduced in favour of other methods of estimating fertility requirements of pasture? This may be possible where straight arable crops are grown for direct human consumption as in Europe, but in New Zealand, where complex pastures are grown for consumption by the grazing animal, field trials may continue to be necessary.

A. No, I don't think so. I am not underestimating the complexity of the problem, and I am not suggesting that it will be possible to replace field trials with other methods of estimating fertility requirements. What I do suggest, however, is that these other methods should be used to improve the effectiveness of field trials, which should be the end point rather than the starting point for many investigations.

Q. (Mr During): Could you advise on whether these newer methods of analysis e.g. the leaching technique, may affect the forms of fertiliser to be used in the future?

A. Yes, it is quite possible that they could. In fact, the use of the leaching technique has already focused attention on the need for different types of fertiliser in some areas.

Q. (Mr Woodyear-Smith): Do the figures in Mr Hogg's table, referring to a copper deficiency of Te Kopuru sand apply to all sandy soils?

A. No, I think the figures can strictly be related only to Te Kopuru sand.

Q. (Dr Brougham): Is there any possibility of devising a chart for each soil type in the country which could show the maximum effect from the local climate. What are your views on this?

A. To do this you would, of course, have to assume that the type of plant material available would give maximum yield. If you could be completely sure that no other factor, such as soil fertility, was limiting production, it could be a possibility. I am a little inclined to wonder whether the results would justify the time which would have to be spent on such a survey.

Q. (Mr Larsen): Does Mr Elliott think the application of slag to blue papa soils is as good as putting it down the drain?

A. I think it is likely that in terms of return for each pound spent on fertiliser it wouldn't be hard to find something better than basic slag. From this point of view I would consider part of the money spent slag as wasted, and therefore no better than putting that part of it down the drain.