TRACE ELEMENTS FOR PASTURES AND LUCERNE

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Of the recent developments in agricultural science few have been more important than those following the discovery of the essential nature of certain trace elements for plants and animals. This is particularly true of Australasia where large areas of land have been found to be deficient in one or more of these essential trace elements.

The discovery of widespread molybdenum deficiency in the soils of this country stimulated the Department of Agriculture to explore other possible deficiencies in our soils, In this talk I shall deal with pasture and lucerne trials carried out with magnesium and sulphur, both major elements, and, with molybdenum, copper! zinc and boron, commonly called trace elements. Vanadmm is included although it is not known to be essential for higher plants.

MOLYBDENUM

It was Davies who in 1945 (2) first reported molybdenum deficiency in New Zealand. Data accumulated since then by means of some 700 trials have shown us that several million acres of land are affected. Unfortunately an insufficient number of these trials in the Wairarapa and Hawkes Bay district makes our knowledge of the subject rather uncertain in that area.

In this talk it is, of course, impossible to deal with our results in detail.

Because among recent trials those in the far north have been the most spectacular I shall discuss them at greater length. In this area particularly north of Auckland it seems that due to molybdenum a marked swing will take place away from basic slag and away from heavy liming towards molybdated super and light applications of lime. A million acres or so is involved. The highly molybdenum responsive soils are the semi-volcanic soils derived from andesitic rocks, most clay soils and some gumland soils. On many of these soils where farmers, often with small holdings, have had an upward struggle to fertilise their land adequately by

orthodox means, molybdenum is causing worthwhile savings and sensational increases in carrying capacity.

When molybdenum is applied growth may be stimulated rapidly but in other instances its effect may not be apparent for a year or two. Delayed responses could be caused by various factors. For instance they may be due to initially high pH resulting from heavy liming or due to a previous dressing of basic slag causing a temporary sufficiency of available molybdenum. As the pH falls, an expression of increasing acidity, or as the effect of basic slag wears off, the effect of applied molybdenum may show up. In one trial, where the original soil reaction was pH 6.2, pastures on the molybdenum treated plots responded for the first time 2½ years after application.

This brings us to the question of how long-lasting is the effect of one dressing of 2½ oz. of sodium molybdate per acre. In a trial in North Otago (on Opuha silt loam, dry phase) 2½ oz. of sodium molybdate was applied in January 1951,. -Today it still gives an excellent response and is as good as a treatment which had received 3 tons of lime (at the same time). The soil on this site is very acid, about pH 5.0.

In the North Island, however, there is some evidence that on some highly responsive clay soils north of Auckland and on soils derived from andesitic rock the residual value of applied molybdenum is not as. high as this.

Short-lived responses to molybdenum have been observed on many occasions in Southern Hawkes Bay and in the Manawatu. A transitory but statistically highly significant pasture response also occurred in a mowing trial at Marton. The soils involved cover a large area, perhaps 200,000 acres of flat and undulating land. In an attempt to solve the puzzle of fleeting responses we are now laying down rates of molybdenum trials.

It is possible that some soils (Matamau and Kiwitea soils), particularly in the southern half of the North Island, may need a little more than 2½ oz. of sodium molybdate per acre. In several trials in the Palmerston North district responses have become more marked when a second dressing of 2½ oz. of sodium molybdate was applied two years after the first application.

Adverse effects on pasture growth following the application of molybdenum are rare but worthy of note. It seems incredible that one ounce of an element spread over one acre should cause a depression of growth. This, however, has happened on a soil near Tauhara

derived from Taupo ash (pumice) and in several other places.

A more serious consequence of molybdenum topdressing could be its toxic effect on animals. A high molybdenum intake tends to accelerate copper depletion in the body. There are two types of soil which are naturally healthy for stock but where applications of molybdenum can be dangerous. There are those which grow pastures with a naturally high molybdenum-copper ratio and those which develop an artificially high molybdenum-copper ratio following molybdenum top dressing at the rate of a few ounces per acre. These soils have been discussed by Cunningham (3). A helpful guide to topdressing of these soils is as follows. Soils of the first group where pastures have a medium or high natural molybdenum content (above 2 p.p.m.) do not show a pasture response to molybdenum applications. Molybdenum topdressing is therefore not advised. On the soils of the second group where the application of molybdenum may give an artificially high molybdenum-copper ratio because it causes an apreciable rise in herbage molybdenum we recommend topdressing with copper before using molybdenum. It would be more economic, however, to find the absolute minimum of molybdenum necessary to stimulate pasture growth on the latter group of soils. If this is done it may be found that smaller amounts of molybdenum than those used at present may suffice as top dressing with negligible effects on molybdenum-copper ratio in the herbage. Unfortunately, however, we do not know all the soils which belong in the second group, that is, soils on which molybdenum topdressing leads to a marked increase of this element in the herbage making it of potential danger for animal health.

VANADIUM

Vanadium has not been proven to be essential for the growth of higher plants but it has recently been shown to be essential to the growth of green algae. (1) Earlier, some workers claimed that it stimulated the growth of clover nodule bacteria but others have wondered if these results were obtained with materials purified enough to preclude error. The action of vanadium is of considerable interest to us in New Zealand because it occurs in relatively large quantities in basic slag.

Basic slag is recognised as superior to straight superphosphate on most of those soils of the North Island which are now known to respond well to molybdenum. Admittedly basic slag contains some molyb-

denum, the equivalent of about one-tenth of an ounce of sodium molybdate in 3cwt. One-tenth of one ounce of sodium molybdate per acre seems rather little to account for the known efficiency of basic slag and hence investigations into vanadium were begun a few years ago. There are about 100 observational trials in progress and two mowing trials which include vanadium as a treatment. Most of these trials were laid down too recently to give us any information at this date. The following facts, however, have emerged from older trials. Vanadium, applied at the rate of one lb. of orthovanadate per acre seems to give no positive results on the highly molybdenum responsive soils near Dunedin. It definitely cannot be used as a substitute for molybdenum there. On the other hand vanadium has given definite responses both with and without molybdenum on the soils derived from andesitic rock in the far north.

In one trial it has stimulated growth in the presence of 2½ oz. of sodium molybdate per acre (on Rangiuru clay) but in another trial (on Whatoro clay) it has improved growth only if applied by itself without molybdenum. And so, in spite of initial scepticism, the preliminary results of a few pilot trials have been definite enough to persuade us to begin more accurate investigations.

On soils which do not respond to "molybdenum no enduring vanadium responses have been reported as yet but on one a clear depression due to the application of vanadium at the rate of 1 lb. of orthovanadate per acre has occurred. (On Pinaki sand).

COPPER

Experiments with copper as pasture topdressing material began shortly after this war on peat soils following a 'report by Cunningham (4) that the use of copper resulted in an apparent pasture improvement at Waitakaruru. Twenty lb. of bluestone per acre was used. However out of 8 of our trials, all on peat, only in one was a consistent slight response to copper reported. (This was on Ruakaka peat and only on those plots which had received 1 ton of lime per acre or more).

Later Rukuhia Soil Research Station demonstrated very marked copper responses in several crops, amongst them lucerne. In contrast, however, to the spectacular results on crops and lucerne only fair responses were observed on new quite vigorous, pasture in an adjacent field.

Work with copper on mineral soils began about two years ago and has already yielded some interesting and promising results. We are conducting at present about ,120 observational trials using mainly copper sulphate (bluestone) at the rate of 10 lb. per acre.

In the North Island pasture responses to this treatment have been observed on a variety of soils, all of which are derived from sedimentary sandstones, from windblown coastal sands, or from soils which were once under kauri and have undergone extreme leaching and soil degradation.

(Puke Puke sand, Pinaki sand in presence of 1 ton lime per acre only, Red Hill sand, Te Kopuru sand, Waikare sandy clay, unmapped fine sandstone north of Palmerston North, Wharekohe silt loam. Three of these soils are also low in available MO, namely Red Hill sand, Te Kopuru sand, Waikare sandy clay),.

While these results with copper. are interesting we should not attribute too much importance to them. In most pasture trials in northern districts copper responses have been only slight and sometimes of a transitory nature.

In the South Island only one pasture response from the application of copper has occurred, but this was an excellent one. A heavy dressing of copper carbonate was used at that occasion. 'The site is Hakataramea Valley.

As it might be an advantage to use heavy dressings of copper in an insoluble form instead of the usual soluble dressings' three mowing trials in the South Island were recently begun with copper-carbonate treatments.

There *is* much scope for trials with copper on the light stony soils and pakihi soils of Westland and on some of the hill soils derived from sandstone in the Wairarapa and Hawkes Bay districts because soils similar to these have been found slightly copper deficient in other parts of New Zealand.

SULPHUR

In spite of the probable widespread deficiency of this major element in New Zealand its study has been neglected. This is because the fertiliser most commonly used in this country is superphosphate which contains more sulphur than phosphorus. Deficiencies have thus been masked by its use. Nevertheless that sulphur has been given so little consideration is surprising because as long ago as 1928 sulphur alone was shown to be as effective as superphosphate in increasing the yields of lucerne in Central Otago (5) and near

Nelson (11). It is only in the last few years that the Department has laid down trials with sulphur in sufficient number to map the deficiency.

I think there is general agreement that in New Zealand sulphur is mainly made available in the soil by mineralisation of organic sulphur contained in the soil humus, although in coastal areas sulphur derived from sea spray may also contribute significantly to plant nutrition.

Soils low in organic matter, soils in which the turnover of organic matter is restricted by climatic and topographic conditions and soils in which organic matter accumulates fairly rapidly under grassland farming are those on which plant responses to sulphur are to be expected ; and here they are in fact obtained.

Soils low in organic matter, on which we have obtained pasture responses to sulphur are derived from Tarawera gravels, erupted as recently as 1886, from Ngauruhoe ash, and soils in Central Otago. Highly fertile silts recently deposited by floods, and low in organic matter may also belong to this group. On these soils good pastures can often only be established with the use of superphosphate. It seems very likely that here too sulphur is lacking.

Soils quite high in organic matter however and high in their total sulphur content may yet be low-in plant available sulphur, presumably because this element is not released in sufficient quantity. This may be caused by dryness, cold temperatures, or the two combined. In practice excessive drainage, steep slope or dry summers perhaps followed by cold winters are the conditions under which sulphur responses are to be found. Soils on steep slopes may be not only dry but also low in organic matter due to erosion,

Sulphur responses attributed to steep slope have occurred on a soil derived from sandstone near Rangiwahia. Outstanding responses to sulphur in North Otago and the Canterbury foothills and good responses on the light gravelly plains soils of Canterbury, Marlborough and Nelson are probably largely due to climate and, in some cases, excessive drainage.

Soils in which the organic matter content is raised appreciably by intensive grassland farming are notably those derived from rhyolitic ash of more recent origin Taupo ash, Kaharoa ash, Whakatane ash). On these pumice soils responses to sulphur might be expected, particularly in those districts where climatic conditions are suitable for their development. Evidence of sulphur responses, however, is so far limited to two or three trials.

Lobb's and Reynolds' observation (7) that pasture responses to sulphur are less likely in fields recently cultivated may explain why good crops can often be grown without the application of sulphur. Nevertheless marked growth responses to sulphur have been recorded on rape.

The application of small quantities of elemental sulphur and perhaps gypsum may, however, lead to complications on soils responsive to molybdenum or low or very high in available manganese. In one trial on a coastal sand (Red Hill sand), a soil on which pastures respond slightly to molybdenum, the application of 28 lb. of elemental sulphur per acre has resulted in a definite depression of pasture growth. Yet a treatment receiving sulphur and molybdenum was slightly better than molybdenum alone, indicating that both sulphur and molybdenum were needed. But while the omission of sulphur was not seriously restricting growth in this case, the addition of sulphur without molybdenum might have, at least temporarily, reduced pasture production by at least 50%. The reason for this depression may be due to a very slight but critical reduction in pH in the very top layer of the soil or perhaps, as overseas researches suggest, to a sulphate ion-molybdenum ion antagonism.

In some trials there is an indication that sulphur may be of some benefit by releasing manganese. This may be occurring on a trial near Waiouru (Waimarino sand) and on one on the "black tar" soil of Oamaru (Waiareka clay).

The type of country in the North Island which may be affected by sulphur deficiencies is the steeper drier hill soils of Gisborne, Hawkes Bay and Wairarapa, some of the pumice soils, and also the light well drained stony soils of the two latter districts. However, except for one trial already mentioned giving a positive response to gypsum on a fairly steep sandstone slope near Rangiwahia, little has been done to confirm this belief by experimental evidence. The question of sulphur deficiency in the North Island becomes only important, however, if double super is used instead of superphosphate. Double superphosphate contains very little sulphur. With our present, admittedly incomplete, knowledge I would advise in topdressing the types of soil mentioned above to give double super a preliminary trial before using it on a large scale.

The effect on pasture growth of sulphur applied as gypsum or in its elemental form may be evident for 2 years but usually declines appreciably after 1½ to 2 years in trials conducted in the South Island,, Con-

versely treatments with sulphur may not be worthwhile until 1½ to 2 years after the last application of superphosphate.

In the North Island and probably on most soils of the South Island phosphorus is needed as well as sulphur to maintain vigour of pastures or lucerne. However, it is not unlikely that on some soils the residual value of applied phosphorus markedly exceeds that of applied sulphur so that in future we may turn increasingly to cheap sources of gypsum for topdressing, and at the same time we may-restrict our use of phosphorus.

MAGNESIUM

Ever since Dixon and Taylor (8) in 1942 found that long-continued topdressing with superphosphate accelerated natural losses of exchangeable magnesium in Waikato soils we have been expecting magnesium deficiencies to crop up. That magnesium has not become a major problem may be due to the widespread use of serpentine superphosphate which contains magnesium (about 9% MgO equivalent).

There are over 100 current observational trials and several mowing trials with magnesium carried out by the Extension, Division. These use mainly magnesium carbonate at the rate of 2cwt. per acre.

In the North Island no outstanding responses to magnesium have been obtained. Very slight improvement, however, following magnesium has occurred on coastal sands but not where lime was applied. (Red hill sand, Whananaki sand, Pinaki sand).

A slight response is also reported from Franklin County on a soil derived from water-sorted andesitic ash. A sister trial on the same soil type in another field in which serpentine super is used has given no response to magnesium. Earlier trials carried out at the beginning of the war report responses to serpentine rock and magnesium sulphate in the Waihi district on soils derived from the Waihi ash shower. Serpentine super is now regularly used in this district and no deficiency symptoms due to magnesium seem to have occurred.

In. the South Island quite good pasture improvement due to the use of magnesium was seen in several trials.

One of the most interesting results has occurred at Marton Experimental Station. In a mowing trial testing the interaction of major and minor elements magnesium applied at the rate of. 3 cwt. of magnesium carbon&e per acre has in itself not improved prod&-

tion. However, if examined in conjunction with the two rates of phosphate applied, ½ cwt. of double super per acre and 2 cwt double super per acre it is found that magnesium has improved the pasture yield on the treatments receiving the low rate of phosphate but not on those receiving a high rate. Magnesium therefore in this case seems to have had a phosphate-sparing action. There was still a response to the higher rate of phosphate in the presence of magnesium but its magnitude was highly significantly lower than that of the response obtained without magnesium. Heavy liming at the rate of 2 tons per acre had a similar effect.

ZINC

Zinc sulphate as a soil treatment is now included in almost 100 observational topdressing trials and in one mowing trial.

Slight pasture responses to zinc have been obtained on several soils derived from coastal sand in the northern part of the North Island (Te Kopuru sand, Pinaki sand and Whananaki sand). This would confirm positive results with zinc obtained by the Soil Bureau in pot trials (9).

In the South Island a response to zinc sulphate is reported from a trial in the Hakataramea Valley and possibly- on a coastal sand in Southland.

A fleeting but marked response which may have been due to zinc has occurred on a farm near Matamata on a peaty pumice soil (Hunga Hunga peaty loam) limed fairly heavily in the past. This result i's being followed up by other trials.

The number of zinc-responsive soils will probably be rather limited but there is some scope for zinc trials on soils derived from poor coarse sandstones in the Wairarapa, Manawatu and other districts, as well as on ironstone soils derived from basalt.

BORON

Boron has aroused considerable interest since experiments in 1936 showed that "mottled heart" of swedes could be almost completely controlled by the use of 10 lb. of borax per acre (10).

Boron deficiency, however, although severe enough to affect brassica root crops may not limit the growth of lucerne. In fact lucerne responses to boron have up till now only been reported from Marlborough and Central Otago.

Clovers and grasses seem to make even better use of soil boron than lucerne for no definite growth res-

ponses to applications of borax have been reported from the large number of trials carried out with this element.

SOILS ON WHICH PASTURES DO NOT SEEM TO RESPOND TO TRACE ELEMENTS

An enumeration of trace element responses such as the one presented tends to give the impression that a considerable area of New Zealand will or may repay the use of these elements. This is not the case. Certainly molybdenum deficiency is widespread and of considerable importance in Otago and North of Auckland as well as in parts of Canterbury, and the Nelson, Sounds. Wellington, Raglan, Coromandel and a few other districts.

Sulphur, not a trace element and occurring in sufficient amounts in superphosphate, is important mainly in the drier and colder parts of New Zealand.

Magnesium deficiency might occur more often were it not for the widespread use of serpentine super.

Deficiencies of copper, manganese and zinc are strictly limited to a few soil types and even then they may only occur if these soils have been heavily limed.

Let us look at those soils where it would seem that no trace elements are required for maximum pasture production. In the North Island they comprise a large proportion of the soils derived from volcanic ash. These soils alone cover about half the total area. We can add to this list the soils derived from mudstone (papa), limestone, most alluvial flats and the large area of terrace soils in the Manawatu and Wairarapa.

In the South Island there are no soils derived from volcanic ash. Instead east of the Main Divide wide areas are covered by windblown silt and fine sands (loess) a proportion of which is molybdenum deficient. But except for molybdenum there is even less evidence of trace element deficiencies in the South Island.

MULTIPLE DEFICIENCIES

By multiple deficiencies I mean cases where more than one trace element is needed for maximum growth of pasture and lucerne.

Several of these occur. In the North Island they are particularly likely on coastal sands and soils derived from sandstone. Molybdenum and copper are mainly involved.

In the South Island lucerne has responded in certain soils to both boron and molybdenum. However the areas which warrant treatment with several trace elements are very small and are known to the Instructors of the Extension Division.

CONCLUSION

In conclusion I should like to say that we have trials with trace elements and sulphur and magnesium on most major soil types of New Zealand. All field officers are anxious to study soil fertility problems, particularly with regard to trace elements, as positive results afford perhaps the most spectacular opportunity to raise production quickly and without great expense. In this they are supported by the Department's chemists who are correlating growth responses to trace elements, sulphur and magnesium with chemical analyses of 'plant and soil. It is of course, the purpose of the chemists to develop chemical methods of analyses which can diagnose nutrient deficiencies and which are reliable enough to be used in advisory work,.

From this combined effort both in the laboratory and the field it appears that the majority of highly-producing soils which are used for dairying, fat lamb and crop production are not at present deficient in trace elements, with the exception of molybdenum. On the other hand deficiencies of major elements are common.

There is today a tendency to turn to trace elements whenever pasture or lucerne are not thriving. But I think it is fair to say that, molybdenum apart, trace element deficiencies are rare. If pasture or lucerne are not thriving, and low nutrient supply is the cause, it is most proper to look first for a lack of phosphorus, potassium, lime or sulphur.

Results from trace elements may be spectacular but they are limited to well defined soil types and conditions, some of which I have summarised in this paper,

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