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TRACE ELEMENTS

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During recent years the importance of the so-called trace elements in plant and animal nutrition has become very apparent, and an enormous amount of work has been conducted in all parts of the world relating to this subject. It is intended in this bulletin to deal with those elements which are proven factors in primary production in New Zealand. Before doing so, let us see which elements belong to this important group of plant and animal nutrients, and why they have become known as the trace elements.

It must be realised that all the elements required for the satisfactory growth of plants have not been shown necessary for animals, and conversely, all those necessary for animals are not required by the plant itself for normal growth, although, of course, the plant remains the normal provider of those elements for the stock. It is important therefore to realise the relation between mineral deficiencies or excesses of plants and the health of animals feeding on them.

As stated in the bulletin on soil testing, the six known trace elements needed for normal plant growth are: iron, manganese, copper, zinc, boron and molybdenum. Of these, no role has yet been found for boron in the animal body. In addition two others, namely cobalt and iodine, while not needed for plant growth, are absorbed by plants, and are needed by stock.

These elements have become known generally as trace elements. because they are needed in very small amounts compared with the major plant foods such as phosphorus and calcium. Whereas the content of calcium in dried pasture is about 1 per cent. and of phosphorus .5 per cent., the usual content of iron or manganese is about 100 parts per million (p.p.m.) or one hundredth of 1 per cent.; that of copper and zinc about one tenth of this, and that of molybdenum only one or two p.p.m. In spite of this, these elements are as important to the plant or animal as the major elements and a lack or over-supply of any one of them will lead to complete or partial failure in plant or animal health and well-being.

Trace Elements in Plant Nutrition

1. Deficiencies: In dealing with deficiencies of trace elements in plants. it is obvious that the reason for these deficiencies lies in the inability of the plant to obtain sufficient supplies from the soil. Here, as with major elements, we run against the problem of the "availability" of the element in question and the various factors which govern the availability. It is well known that while a soil may contain ample "total" phosphate, plants grown on it may suffer from phosphate starvation. The same applies to the trace elements and it is desirable therefore to recognise two main types of deficiency which may occur in soils. The materials from which some soils are derived are themselves naturally deficient in certain elements; consequently the soils are said to have an "inherited" deficiency. In other soils, various factors such as liming may so modify the supply of an element that a deficiency of that element is "induced" in the soil.

2. Excesses: So far the accent has been on deficiencies, but there are two other possibilities to consider, namely, an over-supply of nutrients and the balance between nutrients. Manganese, in very acid soils, may become toxic to plants and plant injury can occur on acid sewage sludges due to abnormally high amounts of copper and zinc. Indeed it is becoming increasingly evident that plant failure on very acid soils is more often due to such effects as these than to the high acidity.

3. Balance of Nutrients: For healthy plant growth it is necessary that the elements be present roughly in certain proportions, and it is also found that in the plant-growth processes, certain elements oppose and others assist each other in their action. Thus, too much molybdenum may cause copper deficiency. This is an example of the first type; an example of a beneficial action is that of potassium, in relieving iron deficiency.

4. Factors affecting the supply of minerals to plants. a. pH: The supply of mineral nutrients to plants is affected by conditions in the soil and the atmosphere. The soil pH (degree of acidity) is probably the most important factor influencing the availability of trace elements. Thus, as the pH rises—i.e. the acidity decreases —iron, manganese, boron and probably zinc become less available, whereas molybdenum alone of the trace elements becomes more available. In strongly acid soils—low pH—on the other hand, molybdenum may be unavailable, whereas the solubility of manganese may so increase as to become toxic. Important from the practical viewpoint is the fact that troubles due to trace-element deficiencies and excesses may often be controlled by pH adjustment. The normal procedure for correction of acidity is of course liming, and for alkalinity, the use of sulphur.

b. Soil Fixation: The clay and humus fractions of the soil, because of their extremely small particle size, have the power to react with the plant nutrients. Sometimes the nutrients are held only strongly enough to prevent leaching or washing out by drainage water, and yet remain available as plant foods. In other cases the nutrients are "fixed" to such an extent that they are rendered unavailable to plants. In the latter event, application of the nutrient to the soil may fail to correct the deficiency. In such cases it is usual to practice either foliage spraying or fertiliser placement.

c. Soil Organisms: The soil organisms undoubtedly play a prominent part in the availability of trace elements; zinc and manganese are two which are affected in this manner.

d. Drainage: Soil drainage, by its effect on the water content and the aeration of the soil, also effects availability. For instance, iron and manganese are usually highly available in water-logged conditions.

e. Rainfall and Light Intensity: Other factors known to exert their influence are drought (in susceptible areas boron deficiency is more acute in dry seasons) and light intensity (which particularly effects the availability of zinc). This summary of some of the factors which play a part in determining the supply of nutrients to the plant should give some idea of the difficulties involved and explain the conservatism with which inquiries on the subject may be met.

Detection of Trace Element Deficiencies

Various methods are employed to detect mineral deficiencies or excesses in plants.

a. Chemical analyses of plant materials.

b. Field and pot culture trials to determine the effect of addition to or omission from the soil of mineral nutrients.

c. Soil analysis. Here the difficulty is the evaluation of the available supply; tests are available for some elements but for the most part they are complex and time-consuming and suitable only for research work.

d. The direct supply of mineral nutrients to the plant by spraying or injection.

e. Visual methods of diagnosis based on known deficiency or toxicity symptoms exhibited by plants.

Frequently recourse must be had to more than one of these methods before a diagnosis can be made. It is unfortunate for this country with its great dependence on grassland, that unless the deficiency is very acute, visual symptoms are not often observed in pastures. Even with annual crops and fruit trees, for which the symptoms are well established, the picture may be so confused by the presence of insect pests and fungus and virus diseases that experience is needed to diagnose confidently from visual symptoms.

Let us now look at the effects on plants, of the individual elements which are of known interest in New Zealand. These are boron and molybdenum, and to a much smaller extent, copper and manganese.

Boron: A deficiency of this element affects apples, turnips and swedes, apricots, grapes, tobacco, raspberries and hops. In North Auckland the deficiency is severe enough to limit the growth of clover in the pastures and it is likely that other areas will be found where legumes need boron. The disease-names in apples (internal cork or corky pit) and root crops (brown or mottle heart) are self-descriptive. In apples there are considerable varietal differences ranging from the very susceptible Sturmer to the almost resistant Dougherty. These diseases may be induced by liming to too high a pH, and are more severe in dry seasons. Boron deficiency frequently occurs on soils of light texture and is particulary prevalent in the Nelson province on the soil of the Moutere Hills and soils derived from granite.

Diagnosis is normally by plant or soil analysis and the trouble is cured by soil application of borax at amounts up to 20lb per acre broadcast, or by spraying crops or trees with a solution of 1lb borax per 100 gallons water. Another alternative is to sow root crops with borated super which contains 2.5 per cent. borax. An excess of boron must be avoided as it can be toxic to plants.

Molybdenum: A deficiency of this element in New Zealand was first noted in cauliflower and broccoli. In these plants it causes the disease known as "whiptail," characterised by distorted leaf-growth and death of the growing point. More recently many plants, especially rape and the legumes, have been found to respond markedly in vigour to applications of 2-3oz per acre of molybdenum compounds, usually sodium or ammonium molybdate. Two methods of application are used for pasture and forage crops.

(a) Mixed with super. Molybdenised super is available containing 12oz sodium molybdate per ton, i.e. 1oz per bag.
(b) Both the above salts are water soluble and may be applied as a spray.

In some cases the response of the clovers in a mixed pasture has been phenomenal, dry-matter production increases of the order of 400 per cent. being obtained. A point of great interest in these trials is that many of these results have been obtained on quite acid soils without the use of lime, and in some cases without super, though overseas work points to phosphate and molybdenum being mutually beneficial. We at the college have been able, by applying molybdenum, to induce new vigour into a very weak stand of lucerne sown on a paddock which had been ploughed out of lucerne three years previously, a procedure which frequently leads to failure of the second crop. Increases in yield and protein content of 25 to 30 per cent. were obtained in the season of application. It is known (see under pH) that liming renders molybdenum available, always provided that it is present in the first place. Consequently it is now apparent that on certain of our New Zealand soils the release of molybdenum has been one of the major beneficial effects of liming. It should, however, be stressed at this point that although the application of 2½oz of sodium molybdate has in many cases produced as much increase in bulk of feed as two to three tons of lime, it would be unwise at this early stage in our knowledge to regard molybdenum as a complete substitute for lime. Lime has been such a tremendous factor in the improvement of our grasslands and performs so many functions other than the release of molybdenum, that to discontinue its use on the evidence of a few trials would be extremely ill-advised and possibly dangerous. There is another point concerning the use of molybdenum. A high molybdenum content in the pasture can pre-dispose stock to copper deficiency; indeed it causes copper deficiency on the so-called "teart" pastures in England. This aspect will be more fully dealt with in the section on animal nutrition. Despite the relatively small amount of work done, it is very apparent that the use of molybdenum offers great possibilities in increasing production in this country. Marked responses have been obtained on many of the downlands soils of Canterbury and Otago, on some of the older, more-leached soils of the plains and on hill-country soils. It is on this last group, where the inability to apply lime has proved such a drawback to pasture improvement, that I think the greatest immediate use will be found for molybdenum compounds. An empirical test for available soil-molybdenum can be carried out and is being extensively used by the Department of Agriculture. Plant analysis is of very little, if any, use. Field trials are probably the surest and quickest way of diagnosing a need for molybdenum. Little is known concerning the optimum rate, the period of effectiveness or the best time and method of application, and anyone desirous of trying molybdenum applications is strongly advised to seek advice from a responsible authority before so doing.

Manganese: In this country manganese deficiency has been shown to occur on citrus and stone-fruit crops. In the latter case it is probably induced through over-liming. The best control method is a spray of the Bordeaux type using manganese sulphate at the rate of 5lb per 100 gallons of water.

Copper: Omitting the cases of application of copper sulphate to pastures for the benefit of stock, which will be dealt with in another section, the only established case of copper deficiency in plants is in onions grown on a peat soil. The extent of the area affected is only a few acres.

It is probable that the gumland soils of North Auckland, which are very strongly leached, are deficient in copper, manganese and zinc but little is known of these at present.

Trace Elements in Animal Nutrition

Of interest in New Zealand in this connection are cobalt, copper, molybdenum and iodine.

Cobalt: The disease known as Bush Sickness, or Morton Mains disease, has long been known to be due to a lack of sufficient cobalt in the diet of ruminants. In sheep particularly, diagnosis is difficult from the clinical symptoms because of their similarity with those of parasitic infestation or poor management. The surest proof of a deficiency is obtained by the use of one or more of the following: (a) Cure following treatment with cobalt. (b) Liver analysis. (c) Pasture analysis. The critical levels of cobalt for (b) and (c) are well established, and by these means it is possible to diagnose cobalt deficiency with some certainty. The incidence of the disease is associated with certain types of soil such as the coarse pumice soils, the pakihi and granite soils, the gumland soils and some gravelly silts and sands. At Morton Mains the soil is a wind-blown silt.

The control methods for this disease are well known and the information readily available. Briefly they are:

by drenching, preferably little and often (intravenous injection is useless as the site of action of cobalt is the rumen), by licks, usually 4oz cobalt sulphate per ton, or by annual topdressing with 2cwt cobaltised super, containing 5oz cobalt sulphate. Attempts at using heavier dressings to last longer have met with only partial success.

Copper and Molybdenum

These two elements are best dealt with together because of their effects on each other. Two types of copper deficiency are at present recognised in New Zealand. The first is a straight-out copper deficiency—uncomplicated by molybdenum. It affects lambs, and cattle of all ages. Adult sheep remain fairly normal though wool yield is sometimes low. Lambs are generally unthrifty, with fragile bones, followed later by development of a paralysis in the form of unco-ordinated movement of limbs which is often induced only after exercise. The symptoms in cattle are similar to these. This type of disease occurs on pastures with a very low content of copper, less than three parts per million. The normal copper content in pasture is taken as 10 to 11 p.p.m.

The second type of deficiency is one which occurs on pastures which though of moderately-low copper content, are also unusually high in molybdenum. These conditions are commonly found on peat soils and cause the disease known as peat scours. The symptoms in sheep are identical with those of the first type, but in cattle additional symptoms occur. These are an acute scouring in spring or after warm autumn rains, loss in condition and production, rough coat and in blacks, loss of colour. Yearlings are severely affected. Both diseases are diagnosed by: (a) clinical symptoms, (b) recovery with copper treatment, (c) liver, blood and pasture analysis.

The soil types affected are: peats (except South Canterbury), coastal sands and certain river silts. The reason for emphasising caution in the use of molybdenum, especially in areas subject to copper deficiency will now be apparent. The control measures for these ailments are similar to those of cobalt and details are readily available. The most common method is the annual application of 5lb copper sulphate (bluestone) per acre, usually applied with superphosphate.

It is probable that a diet which is only slightly deficient in copper or cobalt can cause unthriftiness and loss of production without producing specific symptoms. Such cases are of course difficult to diagnose, but progress is being made through the use of the soil maps now available for most of New Zealand. As these cases of less-severe deficiency occur, in which poor health and production loss may be the only effects, they are mapped and the soil type noted. Then by summing the total area of such soil types, a map of the location and extent of probably deficient land is obtained, and can be used by advisory workers. Such maps are used by the Department of Agriculture and they indicate that for cobalt deficiency, the total area which is probably deficient is 7,500,000 acres, of which less than 2,000,000 are farmed. The area of borderline deficiency is 9,000,000 acres. Two million acres are definitely copper-deficient and 1,000,000 slightly copper-deficient. Of this total 2,000,000 acres are actually farmed.

A few areas have revealed sporadic instances of copper poisoning in sheep, further stressing the need for caution in the use of trace-element compounds.

Iodine

Iodine deficiency, usually in the form of goitre, occurs from time to time, mainly in South Canterbury and most commonly in sheep. In severe cases, lambs may be born dead or may die within a few days. Losses can be very severe. Planned research is difficult because of the sporadic nature of the outbreaks which do not recur regularly on the same farms. The usual cures are licks containing 10oz potassium iodide per ton, or better, drenching with iodine or potassium iodide.

Much work has been, and is being done in New Zealand on various aspects of trace element work. Many problems have been solved, with great benefit to the primary production of the country, and there is no doubt that the ever-increasing knowledge gained through active research will lead to the solution of some of our present-day problems and of others not yet apparent.

Copies of this Bulletin may be obtained from the Secretary, Canterbury Chamber of Commerce, P.O. Box 187, Christchurch.