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THE PRODUCTS AND THE PROFITABILITY:

SOIL MINERALS AND ANIMAL HEALTH

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Abstract: *Mineral status of the grazing animal is largely determined by that of the soil and of the pasture which it supports, and a range of health problems can arise. These include (1) deficiencies, (2) toxicities, (3) metabolic conditions associated with a high demand for a particular mineral and an inability to access mineral reserves, and (4) the accumulation of residues in tissues intended for human consumption at concentrations unacceptable to health authorities. Some problems such as phosphorus (P) deficiency are seen only on pastures which do not receive superphosphate but trace element deficiencies, metabolic conditions and residues are more common on highly improved pastures for several reasons. These include the presence of contaminants in fertilisers, dilution of the supply of minerals in the increased quantity of forage produced, and the higher quality of forage available which increases animal production and therefore the demand for dietary minerals. As a result pasture improvement and renovation may trigger latent mineral problems. In recent years subclinical or marginal deficiencies have been widespread, and now represent a greater cost to industry than the clinical condition. Subclinical conditions are also difficult to identify and transient in incidence. In some situations supplementation is a lower cost option than establishing that a deficiency exists.*

MINERAL PROBLEMS IN THE GRAZING INDUSTRY

Both plants and grazing animals satisfy their mineral requirements directly or indirectly from the soil, but they differ in their need for particular elements. Animals will sometimes respond to pasture dressings of an element when there is no response in plant growth; such elements include sodium (Na), iodine (I), cobalt (Co) and selenium (Se) (Reid and Horvath, 1980). Plants may also grow normally while containing concentrations of Se, molybdenum (Mo) and lead (Pb) which adversely affect animal health.

Animal nutritionists arbitrarily separate dietary minerals into macro- and micro-elements based on the quantities needed to satisfy nutritional requirements. The macro-elements most likely to be deficient are calcium (Ca), magnesium (Mg), P, sulphur (S) and Na. Approximately 20 essential micro-elements have been identified, but most are not of relevance to grazing animals in Australia; those which are sometimes deficient are Co, copper (Cu), Se, I and zinc (Zn). These elements are frequently only a problem in particular areas, thus reducing the number which need to be considered by individual producers. For example P is more likely to be deficient in the wet/dry tropics, Zn in Western Australia, I in eastern Australia and Se in higher rainfall areas.

Some elements are deficient because of particular soil characteristics. Others arise only at times of particularly heavy demand by the animal and may only be a problem because the animal is not able to access body stores sufficiently rapidly. For example a cow may carry large reserves of Ca and Mg in the bones but be unable to access sufficient in late pregnancy or early lactation when the demand is at its peak and dietary sources are inadequate.

Mineral problems may also arise because of excessive intakes of a particular element, possibly exacerbated by another factor. Most minerals including essential elements, are toxic if excessive quantities are consumed. For example Cu deficiency and toxicity are comparatively common and toxicity may be exacerbated if the liver is damaged by the animal consuming plants of the *Heliotropium* (*eg.* heliotrope) or *Senecio* (fireweed) genera.

Other problems arise when minerals accumulate in products destined for human consumption at concentrations unacceptable to health authorities. The livers and kidneys of many sheep and cattle slaughtered in South and Western Australia contain unacceptable cadmium (Cd) concentrations (Langlands *et al.*, 1988). The residue originates from the phosphate rock used in the manufacture of superphosphate. This problem is not seen in eastern Australia apparently because the pasture species that accumulate Cd are restricted to the Mediterranean zone. Most mineral problems need to be considered in relation to the whole soil-plant-animal system. It is frequently following major disturbance to the system such as pasture improvement, that problems arise.

PASTURE IMPROVEMENT AND RENOVATION

Macro-elements

Pasture improvement and renovation increase the macro-

Table 1: Calcium, phosphorus and magnesium contents of the spine, skull and tail of cattle grazing native pasture, native pasture dressed with superphosphate or native pasture dressed with superphosphate and sown with Lotononis *Lotononis bainesii* and White Clover *Trifolium repens*; g/100g fat free DM (Langlands and Cohen, 1978).

Pasture treatment	Ash	Ca	P	Mg
Native pasture	50.1	19.1	9.1	0.38
Native pasture + super	52.5	19.9	9.7	0.38
Native pasture + super + legume	55.3	21.3	10.2	0.45

element status of grazing animals in several ways:

1. the increase in available soil P and S following superphosphate application is often reflected in the concentration of these minerals in the forage on offer;
2. native or naturalised species are adapted to soils of low fertility. They are generally of lower mineral content than introduced species particularly when legumes are introduced in the pasture improvement process;
3. Availability of green material is frequently greater with improved species because they are generally less sensitive to frost-induced senescence. Green material usually contains more Na, S, P and Mg than senescent material.

The bones are a major macro-element store for animals and the effect of pasture improvement on bone composition in cattle grazing in the Grafton district is shown in Table 1.

In extreme cases inadequate bone mineralisation results in "pegleg" and is characterised by lameness and soft bones. It is most commonly seen in the wet/dry tropics during the wet season. Pasture P content is at a minimum during the dry season as is digestibility and N content. As a result animals are often losing weight during this period, the requirement for P is correspondingly low and so is the incidence of clinical conditions such as pegleg.

The adequacy of a particular forage mineral content should be considered in relation to other dietary constituents, the physiological state of the animal and therefore its mineral needs. This also has implications for attempts to economise on the use of superphosphate by developing pasture plants tolerant of low soil P such as Stylo *Stylosanthes* spp., which also have low P:N and P:available energy ratios. Responses to inorganic P supplementation have been observed in cattle consuming such forages (Little, 1968). The extensive use of these legumes could increase the need for inorganic P supplementation of grazing livestock.

Sodium deficiency also occurs in the wet/dry tropics. Sodium concentration in forages varies widely with plant genotype, some native grasses being particularly low in the element. It is an element that deficient animals will actively seek, and this presumably reduces the number of animals at risk.

Concentrations of K in pasture are generally increased by pasture improvement. This may increase the risk of grass tetany. The condition usually occurs on highly improved grass dominant pastures at specific times of year when the supply of available Mg is insufficient to meet the animal's demands. Plasma Mg concentrations are depressed (hypomagnesaemia) and the animal may go into spasms and die. Dutch work (Kemp and t'Hart, 1957) suggests that the risks of hypomagnesaemia are increased when the K/(Ca + Mg) ratio in pasture is greater than 2.2. A recent Australian study (Lewis and Sparrow, 1991) notes that this ratio in a soil extract may also indicate a potential risk.

Micro-elements

Pasture improvement may either increase or (more often) decrease trace element status. Several processes are involved and several implications arise:

1. Pasture improvement is associated with increased pasture growth. If the soil pool of the minerals available for plant uptake is low before pasture improvement, increased pasture production will further dilute the concentration of the mineral. Deficiencies such as those of Se are primarily problems of improved pastures. Pasture production is frequently limited by rainfall, and in years of above average rainfall, pasture growth is increased and a similar mechanism may operate. We (Langlands *et al.*, 1991) observed significant relationships at Armidale between winter rainfall, and the Se status of lambs at birth and their response in growth rate to Se supplementation.
2. Trace element deficiencies are often observed in years of above average rainfall. This is partly attributable to the dilution effect described above. They are also due to increased leaching and to the effects of impeded drainage which affects the oxygen status of the soil and therefore the ionic form of minerals and their availability for plant uptake. Forage concentrations of Mo decrease and Mn increase when waterlogged soils are drained.
3. Soil acidity is frequently corrected by the application of lime. The availability of Mo for plant uptake increases when pH rises. A rise in dietary Mo concentration in improved pastures which usually also contain significant quantities of S compounds degradable in the rumen, may then induce Cu deficiency. Dietary Cu intake is not affected but its availability to the animal is reduced. Copper complexes with the thiomolybdate ion formed in the near neutral conditions of the rumen by the reaction between molybdate and sulphide ions. Copper thiomolybdate is retained on the solid fraction of the digesta and passes out in the faeces. Copper thiomolybdate may also form after absorption and strip copper reserves from the liver. In this case the Cu is excreted through the bile. There is increasing evidence that Mo-induced Cu deficiency has more deleterious effects on the grazing animal than simple Cu deficiency. In other words the benefits of Cu supplementation are attributable primarily to its ability to counter Mo-poisoning by forming the Cu thiomolybdate complex and less significantly to its ability to supplement the animal's Cu requirements.

4. Pasture improvement is often associated with an increased stocking rate, which may affect mineral status because of:
   - increased soil consumption. Soils are a useful source of trace elements such as Co and I, but elevated iron (Fe) intakes may depress the availability of Cu;
   - increased risk of gastro-intestinal parasitism which increases the requirement for several minerals;
   - changes in the form in which the mineral is recycled to the soil. At higher stocking rates more of the pasture grown is consumed by animals, more is excreted in faeces and urine, and less returns to the soil in litter. This may change (1) the chemical form of the element and thereby affect its availability for plant uptake; (2) may increase losses from the system, for example from volatilisation; and (3) may change the spatial distribution of the element as sheep camps are formed. We have observed a depression in Se status and an increased response to supplementary Se at higher stocking rates (Langlands *et al.*, 1991).

SUBCLINICAL AND MARGINAL DEFICIENCIES

For many years most interest lay in the effects of severe mineral deficiencies which result in obvious lesions such as white muscle disease or goitre. Producers in areas subject to particular deficiencies became familiar with these lesions and were able to take corrective measures when problems arose. Emphasis has now shifted to marginal deficiencies which do not show obvious lesions but do depress production. They have several implications for producers:

1. There are no overt signs that a subclinical problem exists and laboratory assistance or supplementation trials are needed to confirm their existence. If clinical cases have been observed in the past, there is an increased likelihood of a subclinical condition.
2. Laboratory tests vary in their cost and reliability. Properties drift in and out of deficiency depending on the factors discussed earlier such as rainfall or implementation of a scheme of pasture improvement so that a test or trial at one time may only indicate a possible response at another. In some situations, supplementation is a lower cost option than establishing that a deficiency exists.
3. More properties are affected by marginal than by severe deficiencies and it is therefore more likely that a particular property will suffer from the problem. For example in a study associated with the Brucellosis Eradication Scheme, Langlands *et al.* (1981) found that as many as 25% of properties in the Glen Innes district on the Northern Tablelands of NSW were at risk of subclinical Se deficiency, and it seems likely that between 15 and 30 million sheep will be at risk nationally from this deficiency alone.
4. The condition is not only difficult to identify at the farm level but it is also difficult to determine whether a supplementation program is effective. For example subclinical Se deficiency is widespread in southern Australia and adversely affects wool production, lamb growth and survival of lambs. The intra-ruminal Se pellet is widely used to correct the problem but has had a long history of premature failure. As a result producers may incorrectly believe treated animals to be protected against subclinical deficiency. Supplementation strategies such as the Se pellet need to be reliable to combat subclinical deficiencies effectively. In recent years we have examined the factors which affect the longevity and reliability of intra-ruminal pellets and now have a formulation with a reliable 3 to 5 year life which I hope will soon be available commercially.
5. Subclinical Se and Co deficiencies have been reported in Australia, and it seems likely that subclinical Cu deficiencies and Mo toxicities may also be a problem. There is also a lack of information on levels of the diagnostic indicator at which subclinical conditions affect productivity, and the factors that affect them. For example blood Se concentrations or glutathione peroxidase activities are a poor indicator of responsiveness to Se supplementation in cattle but they are reliable in sheep.

MINERAL INTERACTIONS

Mineral metabolism in animals as in plants and soil is characterised by interactions between minerals. Twenty years ago over 70 interactions between minerals had been identified in animals and the number continues to increase. Some are well known like the Cu-Mo-S interaction discussed earlier, while others are mainly of theoretical significance.

An interaction between Se and I has recently been identified and may have implications for producers on the Northern Tablelands of NSW. Both I and Se deficiencies occur in this region. I deficiency arises because the soil is low in I or may be induced because some pasture plants and especially white clover (*T. repens*) contain elevated concentrations of cyanogenic glycosides. These are broken down to cyanide and react with S in the rumen to form thiocyanate. This ion blocks the uptake of I into the thyroid gland which impairs its ability to synthesise the hormones, thyroxine (T4) and tri-iodothyronine (T3). Most T3 is formed outside the thyroid from T4, and it is now known that the enzyme responsible for this transformation contains Se, and that as a result Se deficient animals produce less T3. Since T3 is several times more potent than T4, Se deficiency may exacerbate the effects of impaired I metabolism on thyroid function. The thyroid regulates many processes including body temperature, growth and wool production.

CONCLUSIONS

Australian soils in their original state are infertile, and the vegetation supported is characteristically low in digestibility and protein content for much of the year. The level of animal production, and the mineral needs of the animal are also low and mineral deficiencies must be severe for major animal health problems to occur.

Pasture improvement and related practices may increase both the quantity of pasture produced and its quality. The increased quantity can result in a dilution effect and a reduced concentration of some minerals in the available forage while an increase in quality results in increased production per animal and an increased demand for minerals. Both effects increase the likelihood of mineral deficiencies.

The recognition of the economic significance of subclinical deficiencies and their widespread distribution means that producers need to be alert to mineral problems following changes in husbandry practices. Unfortunately fertile soils and high quality pastures do not always lead to satisfactory animal production, and at such times the existence of a problem of mineral origin should be considered.

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