

AN INTERPRETATION OF THE FORAGE MINERAL REPORT

Introduction

Forages exert a significant influence on the mineral composition of the total diet of ruminants. Consequently, a knowledge of the mineral status of grass as a forage crop is necessary to ensuring diets for cattle and sheep are well balanced in terms of mineral supplementation.

The following notes are designed to firstly provide a summary on the dietary source and role of each of the minerals and secondly, to assist in the interpretation of the forage mineral report. Minerals have a disproportionate effect on animal production relative to their low concentration in total diets. Information on forage mineral supply is the starting point to balancing diets by providing an appropriately balanced mineral supplement.

MACRO-ELEMENTS

Calcium

Calcium is the key mineral element due to its relationship with soil pH, which controls the uptake of many trace elements into the plant. Both from a crop and animal standpoint this element has an influence far wider than its relatively small requirement.

Calcium is required mainly in cell elongation and division. It is found primarily in cell wall structures, where it can exert a significant effect on cell integrity, which in turn has consequences for the quality of the crop.

The pH of a soil depends largely on the amount of exchangeable Calcium present in soils. As Calcium is often the dominant ion on soil particle ion exchange surfaces, it prevents Hydrogen ions from becoming attached, which in turn cause low pH and acidity.

Calcium is, therefore, a key indicator of likely soil pH conditions, which tend to be higher in temporary leys and calcareous soils. Also the Calcium level tends to rise as the plant matures due to its association with the fibre fraction, although the pH factor remains the major influence.

From the forage report a relationship between Calcium and other minerals can often be seen. For example, a high Calcium is usually associated with a depressed Manganese, Copper, Zinc and Cobalt content. In contrast, Calcium is also responsible for increasing the solubility and uptake of molybdenum, which plays a key role in determining Copper availability. In this way, Calcium exerts a fundamental influence on the mineral status of grass and its nutritional value to the ruminant.

Phosphorus

Phosphorus exists in many forms, within the plant and within the soil. The form taken up by the root is dependent on soil pH, but is often in the form of the Hydrogen Phosphate ion. An energy dependent absorption mechanism exists in

the root for Phosphorus uptake, hence grass is less influenced by Phosphorus levels in the soil.

Phosphorus has a major role in the plant through its inclusion in the ATP molecule and the provision of energy.

In hill areas, responses to Phosphorus have been found where soil levels are extremely low.

An important ratio for Phosphorus is its relationship to Calcium. For both plants and animals, the ratio should not be less than 1.5:1, with 2:1 being the optimal target.

A high Phosphorus level in the silage has no adverse consequences, other than its relationship to Calcium and the fact that it is wasteful.

Magnesium

Of the macro-elements, Magnesium has the lowest requirement for plant growth. It is required for the production of Chlorophyll, where 25% of the plant Magnesium is used. The remaining proportion is required for numerous enzyme systems.

Magnesium, like Potassium is associated with clay soils and is in the divalent ionic state.

As for the animal, high levels of Potassium will depress the uptake of Magnesium and the K:Mg ratio should be looked at when applying Potassium fertiliser.

Absorption is as the Mg^{2+} ion and this element is highly mobile in the plant. High levels of Magnesium uptake are not usually a problem for the plant due to its minor level compared, say, to Potassium. Clearly, for grazing livestock a higher level can be beneficial for the prevention of staggers and tetany.

Potassium

Potassium is the second most important plant nutrient after Nitrogen. Its role in the plant is to regulate the cell water content, which in turn controls transpiration and therefore indirectly most plant processes.

Potassium is strongly influenced by soil texture and specifically the clay content, where it represents a major surface ion. It is in equilibrium with the soil solution in the form of the K^+ ion, which indeed is the form it is taken up by the plant. Soil containing low levels of clay minerals or very acid soils generally have low levels of Potassium, leading to deficiencies in the pasture.

Grass, particularly second and third cuts, usually respond well to Potassium fertiliser.

Potassium has two key ratios:

- (a) Potassium to Magnesium ratio in the complete diet of the ruminant should be around 5-6:1. Note in grass the ratio is 14:1. The suppression of Magnesium absorption by Potassium is well known, the danger period being the spring, when Magnesium supplementation designed to balance Potassium is necessary.
- (b) Potassium to Sodium ratio, again for the animal should not exceed 6:1 in the total diet, otherwise electrolyte balance will suffer.

Sodium

Sodium is not an essential mineral for most plants, including grass. Potassium can quite adequately perform the role of controlling osmotic function on its own. However, in situations of very low Potassium, Sodium can take over part of this water regulation role. The level of Sodium in plants is very much a function of the level in soil and the competition from other ions such as Potassium.

If Sodium levels become too high, then a displacement of Potassium and a breakdown in soil structure occurs. However, maintaining adequate soil levels is an important constraint on Potassium uptake by grass, otherwise an increased incidence of staggers and milk fever is likely.

For animals, the K:Na ratio is important and has previously been discussed. However, there is evidence that the "palatability" of pasture grass is enhanced when Sodium levels are at average or above average levels. Conversely, pasture grass may be less palatable when Sodium levels are low.

Chloride

Chloride is the anion of the element Chlorine, which is the form this essential element exists within plants and animals. It is closely related to Sodium and to a lesser extent Potassium. These minerals are called "electrolytes" because of their involvement in maintaining acid-base equilibrium. This is crucial to water balance, nutrient intake and the transmission of nerve impulses.

Chloride is an acid ion, representing two-thirds of acidic ions in the blood. To maintain an acid-base equilibrium, Sodium is required as the base or alkaline ion. The relationship between these elements determines the volume of water in the body and whether cellular fluids are acid or alkaline in nature. This in turn can influence other minerals such as Calcium, which is more available under acid conditions. As a consequence, pre-calving acidic diets have been developed to exploit this relationship, and so reduce the incidence of milk fever in dairy cattle. Chloride is also found in gastric secretions as the anion of hydrochloric acid, which is important for protein digestion.

Chloride dietary requirement in dairy cattle is higher than for Sodium, because of twice as much Chloride in milk (1150 ppm chloride vs 630 ppm Sodium). Typical dietary requirements are 0.20-0.30% Sodium and 0.6-0.8% Chloride (dry matter basis) for dairy complete diets. Chloride deficiency in dairy cows has been shown experimentally to result in decreased bodyweight and milk production. Depraved behaviour such as urine licking, chewing wooden stall dividers and eating soil has also been related to Chlorine deficiency, separating the two effects under practical conditions may be difficult.

Chloride levels are generally high in grass forages (0.8-1.2%), but lower in maize or whole crop silages (<0.5%). However, as salt (Sodium Chloride) is commonly used as a source of Sodium, the likelihood of low dietary levels is small. Problems can arise sometimes when maize silage (low Sodium and low Chloride) is used in conjunction with caustic treated wheat (high Sodium, low Chloride). In this case no salt is added, and dependent on the raw material composition of the diet, Chloride levels could be low. To identify potential problems, Chloride is included in the DIET MINERAL CHECK where dietary supply and requirements

can be compared. In addition, the dietary Chloride level, together with Sodium and Potassium is used to calculate a dietary cation-anion balance (DCAB). This ratio indicates whether the electrolyte balance in the total diet is appropriate for high-yielding or dry cows.

Chloride levels in the Forage Mineral Report are inevitably higher than for Sodium, with Potassium being the electrolyte cation of choice for growth and development. Chloride is used as one of the balancing anions and consequently this exaggerates further the difference between Sodium and Chloride levels in forages.

Chloride levels in grass forages can either be derived from proximity to the sea, the use of grassland fertilisers containing salt or slurry, or more rarely from specific soil types which maybe high in Chloride, usually coastal soils.

Chloride is an essential electrolyte mineral. With diets for dairy cattle becoming more dependent on alternative forages and a wider range of ingredients, an appreciation of the Chloride level in the total diet and its effect on the dietary cation-anion balance is becoming increasingly important, to maintaining health and production in high yielding herds.

Sulphur

In the past it has been assumed that sufficient atmospheric Sulphur has been deposited on pasture to meet the crop's requirement. With pollution, particularly from coal burning power stations being reduced, Sulphur can be limiting in some cases. Yield responses on second and third silage cuts have been reported.

Sulphur is taken up by the plant mainly as the Sulphate ion, although leaves can also take up a small amount of Sulphur Dioxide. In the plant, Sulphate is reduced to organic forms of Sulphur which form the basis of Sulphur containing amino acids, hence the relationship to Nitrogen, where a ratio of 14:1 Nitrogen to Sulphur is considered necessary for optimal protein production.

Sulphur is often on a knife-edge in grass. Too little and growth suffers; too much and it has a progressively antagonistic effect on Copper availability through the formation of Thiomolybdate complexes in the anaerobic conditions of the rumen.

TRACE ELEMENTS

Manganese

This element is the most sensitive trace element to soil pH. Again, being most soluble and available under acid conditions. The plant has a requirement for Manganese, which is used mainly in numerous enzyme systems.

Manganese deficiency can occur easily in neutral to alkaline soils. It has a close relationship with Iron, and care must be taken to ensure the Fe:Mn ratio does not exceed 2.5:1 in the total diet of the ruminant, as Iron will easily reduce the availability of Manganese to the animal. Manganese in ruminants is important for fertility (embryo survival) and bone development.

Copper

As with the other essential trace elements, Copper is sensitive to pH, with solubility being greatest under acid conditions. Levels tend to be higher in mature pastures and lower in temporary leys, primarily due to soil pH factors. Copper is unique of all the trace elements in that it has a great affinity for Molybdenum and Sulphur in the anaerobic conditions of the rumen. This relationship is well known and several regression equations have been developed to link Copper availability with the intake of these antagonistic elements. Copper essential for fertility (initiating oestrus) and energy utilisation in livestock.

Zinc

Zinc deficiency in grass is fairly rare. This element, again, is sensitive to soil pH but probably not to the same extent as Manganese or Copper. Within the animal it is important to ensure that the Zn:Cu ratio does not exceed 4:1 in the total diet, otherwise Zinc will depress the uptake of Copper. About half of the body Zinc is found in surface tissues such as skin, hair, wool, horn and feet. Consequently Zinc has a key role in minimising the occurrence of lameness and high cell counts.

Cobalt

Grass does not have a requirement for Cobalt, although of course it is an essential element for the production of Vitamin B12 by rumen microbes. Again, Cobalt is sensitive to soil pH, being more available under acid conditions. Modern pastures tend to be low in Cobalt for this reason and the fact that British soils are low in this element. Foliar feeding with Cobalt Sulphate is a well accepted method of raising forage Cobalt levels. In ruminants, Cobalt/Vitamin B12 is essential for health and growth/development, particularly in young stock.

Iodine

Iodine is an element similar to Cobalt and Selenium in that while it is essential for animals, plants have no requirement. British soils are low in Iodine and consequently forage levels reflect this poor status. The only exception to this are coastal sites where wind driven sea spray will increase soil and forage levels. In general, more than 90% of iodine requirement has to be provided in the diet.

Iodine is essential in animals for maintaining thyroid function (important for energy use), fertility and health.

Selenium

Selenium is essential for animals and not for plants. Forage levels tend to increase as soil pH rises, however, a body of opinion exists which believes Selenium uptake is reduced by high Nitrogen/Sulphur applications. Forage applications of Selenium salt are not recommended, deficiency should be corrected through the feed route. British soils are inherently deficient in Selenium, although this element is essential for health and fertility, which is exerted largely through its antioxidative role.

Boron

Boron is a trace element which is recognised as being essential for plants, however, the jury is still out on its essentiality for animals although evidence is steadily growing on its role in supporting Calcium utilisation, through its action on activating Vitamin D3. During this interim period of determining whether Boron is essential for livestock and, if so, what is the minimum dietary requirement, the opportunity is being taken to collect data on the background levels in forages and feed materials.

Iron/Aluminium

Soil naturally contains high levels of Iron (5%) and Aluminium. Indeed the clay fraction of soil is largely composed of Alumino-Silicate complexes.

The uptake by the plant is largely influenced by soil pH; with maximum solubility and absorption occurring under acid soil conditions.

The plant has a requirement for Iron, whereas Aluminium is a contaminant and can cause toxicity in ruminants if levels exceed 1,000mg/kg DM basis. Ideally, levels in forages should not exceed 300mg/kg DM basis.

Of course, Iron and Aluminium levels can be high in silage due to soil contamination and sometimes it is difficult to judge where the Fe/Al is high due to contamination or soil pH. A Titanium analysis is the only sure way to establish whether soil contamination is involved, as Titanium is present in soils but not absorbed by the plant. This is the basis of the "Soil Contamination Index" at the bottom of the report. Usually, an assessment of likely soil pH from Ca, P, and Mo analysis is made to determine the likelihood of which route is responsible for the high Fe/Al levels.

Action to reduce the Fe/Al levels of low soil pH can be difficult due to the practical limitations of using lime on upland pastures.

Molybdenum

In contrast to other trace elements, Molybdenum becomes more soluble in the soil under anaerobic and alkaline conditions, due to its displacement from soil particles by Calcium and associated ions. Grass has a requirement for Molybdenum, although deficiency is very rare under practical conditions. Usually, forage levels are excessive and at levels where they interfere with Copper absorption in the ruminant. As manipulating soil pH is the only way of controlling Molybdenum uptake, regular soil testing is essential to keep this element under control. Molybdenum not only suppresses Copper in the rumen but it also will interfere with fertility through reducing the production of oestrogen. Hence so called "Copper deficiency infertility" is usually a combination of forage low Copper and high Molybdenum levels.

Lead

Lead is a potentially toxic element and represents the most frequent cause of poisoning in ruminant livestock. High risk areas are usually associated with historic mining activity, but the application of sewage sludge in the distant past may also be a contributory factor. Lead is poorly absorbed by plants and consequently the highest risk to livestock is from soil contaminated forages.

Summary

Of the 92 elements in the earth's crust, 15 are currently recognised as being essential for animal production. An adequate dietary mineral supply and balance is a prerequisite to ensuring optimal production, health and fertility in ruminants.