Macro-Minerals in Forages Relative to Cow Requirements

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Mineral imbalances or insufficiencies may have a major impact on milk production and on the health and fertility of dairy herds. Pasture-based dairy herds are generally supplemented with minerals in their concentrate allocations. However, given that the mineral composition of forages varies widely, mineral nutrition presents a particular challenge for nutritionists, with the danger of sub-clinical effects being an ever-present concern. In this article we will be considering the macro-mineral [phosphorus (P), calcium (Ca), magnesium (Mg), potassium (K) and sodium (Na)] concentrations in some important forages, and how these relate to the requirements of high-producing dairy cows.

Typical macro-mineral concentrations in pasture species and maize silage are shown in Table 1. Also listed are the required mineral concentrations for lactating cows. Clearly, there is significant variation between forage species with respect to mineral concentrations, and in particular in terms of the concentrations of Ca and K.

Table 1: Typical macro-mineral concentrations in forages grown in South Africa, and concentrations necessary to satisfy the requirements of lactating cows.

	Ca	P	Mg	K	Na
	----------	----------	% in dry matter	----------	----------
Ryegrasses	**0.49**	**0.37**	**0.34**	**3.74**	**0.33**
Kikuyu	**0.34**	**0.36**	**0.31**	**3.27**	**0.05**
White clover	**1.35**	**0.38**	**0.34**	**2.70**	**0.20**
Lucerne	**1.44**	**0.35**	**0.40**	**2.00**	**0.11**
Maize silage	**0.21**	**0.19**	**0.19**	**0.95**	**0.05**
Requirements:					
New Zealand*	**0.44 – 0.55**	**0.37 – 0.42**	**0.2 – 0.3**	**0.44 – 0.45**	**0.10 – 0.11**
NRC#	**0.58 – 0.66**	**0.37 – 0.41**	**0.20 – 0.25**	**0.90 – 1.00**	**0.18**

* From Holmes *et al*., 2002. *Milk Production from Pasture* (Massey University). (Variations in the efficiencies of absorption by cows of individual nutrients in pasture herbage are accommodated in these data)
# National Research Council, 1989. *Nutrient Requirements of Dairy Cattle*. National Academy Press, Washington.

What is not indicated in Table 1 is that there may be considerable variation in mineral concentrations within a particular species. This variation is related mainly to the following factors: (1) stage of maturity of the forage, (2) soil nutrient levels, and (3) seasonal effects. Stage of maturity has a major impact on forage composition, with concentrations of K and P, in particular, decreasing with increasing age of the regrowth. The implication is that ryegrass grazed at the two-to-three leaf stage contains appreciably higher concentrations of P and K (and protein!) than would be the case if grazing was at the three-to-four leaf stage.

Calcium and phosphorus balance

Due to the large amounts of Ca and P in milk, lactating dairy cows have relatively high requirements for these minerals. Legumes are rich in minerals, and in particular Ca, while at the other end of the scale, maize silage is low in minerals. Phosphorus concentrations in most pastures are adequate for lactating cows, and fertilizing to increase herbage P to higher concentrations than the indicated animal requirement has been found to have no beneficial effect on cow performance. In fact, in Europe every effort is being made to restrict herbage P levels because of environmental concerns.

Kikuyu is the only forage species that invariably contains less Ca than P. Many animal nutritionists are of the view that in terms of ensuring that the Ca requirements of animals are met, the Ca:P ratio should be >1, and preferably closer to 2:1. Interestingly, research in KwaZulu-Natal has revealed marked seasonal effects in kikuyu uptake of minerals, with Ca concentrations being at a minimum and P at a maximum in the January to March period. The net result of these trends is that the Ca:P ratio is lowest in mid-summer (when growth is at a maximum), and higher in early summer and autumn (Figure 1). Of further concern is the fact that the imbalance with respect to Ca is aggravated by the high levels of oxalates found in kikuyu. Oxalates form insoluble complexes with Ca, thereby reducing its availability for absorption by animals. In field trials it was found that large additions of lime and gypsum were of limited value in terms of improving Ca levels in kikuyu. However, since high soil K concentrations strongly inhibit uptake of Ca, an important strategy is to not allow soil K levels to exceed the range required for optimum growth (100 to 150 ppm in most soils).

Kikuyu pastures on the Alexandria coastal belt have been found to contain appreciably higher Ca levels than those in KwaZulu-Natal, and consequently the Alexandria pastures have generally more favourable Ca:P ratios.

Potassium and dry cows

Potassium is always in surplus in forages (Table 1), with concentrations in ryegrass and kikuyu frequently being four to seven times higher than cow requirements. This discrepancy is essentially unavoidable since grasses receiving adequate N need to contain about 3% K for optimum growth. However, a particular concern is the tendency for grasses to take up more K than is required for growth, if soil K levels are excessive ('luxury-uptake'). Concentrations of K of up to 6% have been measured in ryegrass growing in KwaZulu-Natal, and it is not unusual for kikuyu to contain 5 to 5.5% K. Excessive applications of N fertilizer promote luxury K uptake. With increasing K uptake there are marked decreases in the concentrations of Ca, Mg and Na (Figure 2), as well as increases in the K/Ca+Mg equivalents ratio (when this ratio exceeds 2.2, absorption of Mg by animals is severely impaired).

There is mounting evidence that high K levels in forages are inimical to the health of dairy cows. Excessive K is particularly problematical in dry cow rations, where it is reported to increase the likelihood of milk fever, udder oedema and the delayed expulsion of foetal membranes. Furthermore, a low or negative DCAD (dietary cation-anion difference), essential in the last three to four weeks before calving in order to minimize the risk of milk fever, is almost impossible to achieve on well-fertilized pastures.

It is worth noting that, relative to grasses, maize silage is low in K. So in addition to its many other benefits in the diet of dairy cows, feeding of maize silage is an effective means of diluting the high K concentrations in pastures.

Magnesium

Magnesium should, for a number of reasons, receive particular attention in pasture-based systems. In the first place, cows have limited mobilisable body reserves of Mg, and consequently deficiencies can develop rapidly, particularly in early lactation. Secondly, Mg availability to animals in young, high-protein grass is extremely poor. And thirdly, high K levels reduce Mg uptake by plants and also its absorption by animals. In noteworthy research conducted in KwaZulu-Natal, Trevor Dugmore found that Mg

supplementation of a dairy herd grazing kikuyu in summer and Italian ryegrass in winter resulted in a significant improvement in fertility.

The use of dolomitic lime to control soil acidity is a cost-effective means of ensuring that pastures contain sufficient Mg.

Sodium

There is often considerable variation in the Na content of forage plants. Some species, such as maize, lucerne and kikuyu, contain insufficient Na in terms of animal requirements, regardless of Na levels in the soil. Ryegrasses, white clover, cocksfoot and oats, on the other hand, readily accumulate large amounts of Na. In fact, in the case of these species, it is possible to substitute a substantial portion of their K requirements with Na, and we are currently fine-tuning soil recommendations so as to exploit this phenomenon. It is worth noting that in coastal areas, considerable amounts of Na are deposited on herbage in the form of sea-spray, resulting in even low Na species such as kikuyu supplying adequate amounts of this nutrient for cows.

Practice Points

1. Excess K is bad news. Potassium fertilization should satisfy pasture requirements for growth, and regular soil testing (0 to 100 mm sampling depth!) is essential to ensure that K levels do not become excessive.
2. Kikuyu invariably contains insufficient Ca and Na for dairy cows. Supplementation should take this into account.
3. The younger the pasture regrowth, the higher the concentrations of K and protein. Beware of rotations that are too short (fast rotations).
4. Legumes are rich in minerals and their inclusion in the diet is an effective means of improving mineral supplies to animals.
5. Liming soils is a wise investment. Dolomitic lime is rich in Ca and Mg, and using it to raise soil pH levels (reduce acid saturations) results in vastly improved mineral supplies to animals.

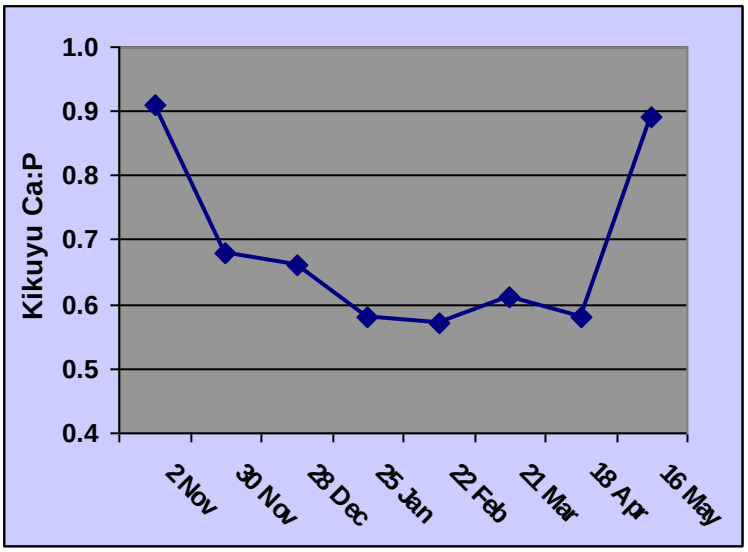

Figure 1: Seasonal variation in the Ca:P ratio in a kikuyu pasture in the KwaZulu-Natal Midlands

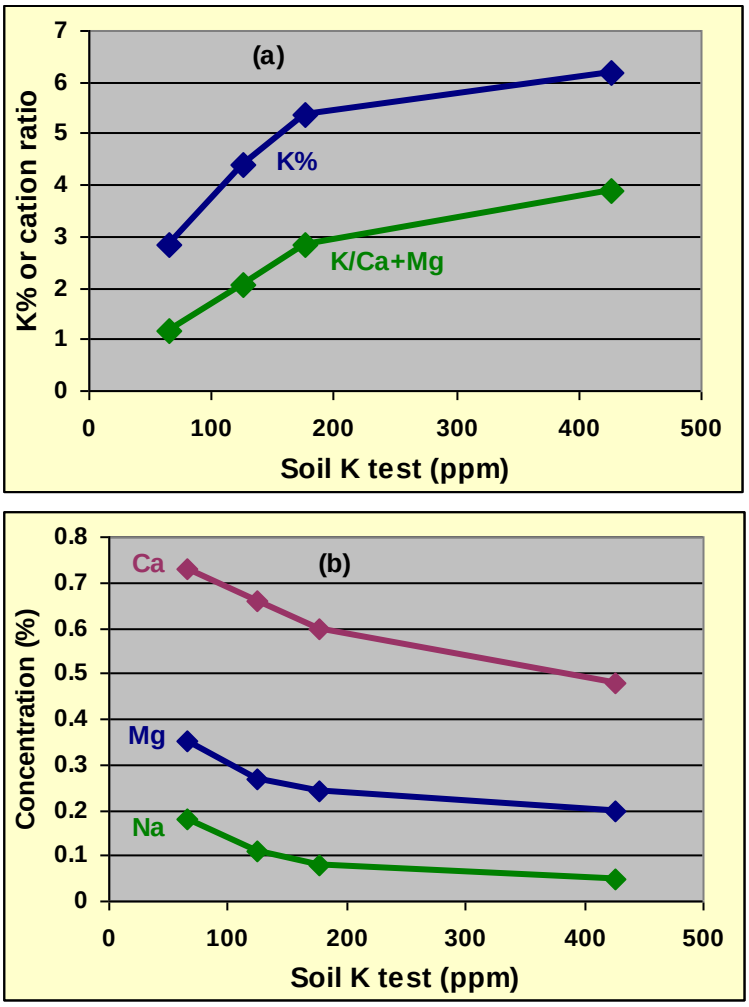

Figure 2: Effects of increases in soil K on the composition of ryegrass. (a) Grass K concentration and the K/Ca+Mg equivalents ratio; (b) grass Ca, Mg and Na concentrations.