MINERAL STATUS OF BEEF COWS AND SHEEP ON SPRING PASTURE FERTILIZED WITH KIESERITE

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Summary

The utilization of minerals in orchardgrass (Dactylis glomerata L.) fertilized with kieserite (2,240 kg/ha) was examined in spring with lactating beef cows and wether lambs. Kieserite increased the concentration of Mg in vegetative herbage from .22 to .29% (P<.01) and of S from .20 to .29% (P<.01), with little effect on other minerals. Fertilization also increased (P<.01) apparent absorptions of Mg and S by lambs fed cut orchardgrass, from 24.5 to 36.5% and from 58.6 to 66.9%, respectively, and increased (P<.01) apparent Mg retention from +.16 to +.33 g/day. Fertilization did not affect dry matter digestibility or apparent absorption of N, Ca or P by lambs. Composition of blood and saliva of beef cows grazing fertilized and unfertilized pastures was determined during a 2-week period in early spring. Cows grazing kieserite-treated pastures showed a small increase (P>.05) in serum Mg, ultrafiltrable Mg and red blood cell (RBC) Mg, and fewer cows on the fertilized pastures showed severe hypomagnesemia (<1.0 mg/100 ml) after the first day of grazing. The decline in blood Mg concentrations was not accompanied by hypocalcemia or by changes in serum Na or K concentrations, but serum inorganic P decreased (P<.01) markedly during the first 10 days of grazing. Ultrafiltrable Ca in blood was affected by fertilizer and period, but it is questionable whether either ultrafiltrable Mg or Ca would provide a more sensitive index of mineral status than serum concentrations. Concentrations of K, Na and P in saliva were more susceptible to fertilizer and period effects than were concentrations in blood, although all values fell within a normal range. There was no evidence of an inverse relationship between serum Mg and concentration of K in saliva of cows after a change from a winter-type diet to spring herbage containing high levels of N and K.

(Key Words: Orchardgrass, Magnesium Fertilization, Blood Minerals, Saliva.)

Introduction

In previous studies (Reid et al., 1978a, 1979b), the application of kieserite (MgSO\(_4\) · H\(_2\)O) to grasses and legumes harvested as hays and fed to sheep significantly increased Mg concentrations in the forage and apparent Mg retention by the animal. High levels of kieserite (448 kg Mg/ha) also increased dry matter intake of alfalfa hay (Medicago sativa L.) by sheep during the first 2 years after application of the fertilizer. In trials with wintering beef cows (Reid et al., 1978b), supplementation with Epsom salts (MgSO\(_4\) · 7H\(_2\)O) in the water or with magnesium oxide in a grain mixture increased serum Mg concentrations and, in 2 years out of 3, increased weight gains of cows during late pregnancy. Recent studies with timothy hay (Phleum pratense L.) showed that both Mg supplementation (as Epsom salts in water) and Mg fertilization (390 kg Mg/ha as MgSO\(_4\) · H\(_2\)O) increased Mg concentrations and apparent Mg retention in lambs, and that the supplement increased level of consumption of the timothy hay (Reid et al., 1979a). It would appear that, in addition to having a function in the prevention of hypomagnesemic tetany, supplementary Mg may play a role in improving forage utilization, possibly by increasing feed intake.

The use of different forms of Mg fertilizer to prevent hypomagnesemic tetany in dairy and
beef cattle has been examined extensively in European countries and in New Zealand, but not to any degree in the United States. It has generally been found that, on fine-textured or neutral to alkaline soils, high levels of fertilizer may be necessary to increase the concentration of Mg in herbage sufficiently to prevent tetany (Grunes et al., 1970; Metson, 1974; Mayland and Grunes, 1979). Trials in which low to moderate levels of kieserite (equivalent to 168 kg Mg/ha) applied to orchardgrass in spring were compared to Mg offered as commercial molasses-MgO blocks indicated that the Mg supplement was more effective in maintaining serum Mg concentrations in lactating beef cows during the first 2 weeks of grazing (Reid et al., 1976). A problem connected with supplementation techniques for tetany prevention, however, is high variation among animals in their use of the supplement, regardless of whether it contains palatable ingredients such as dried molasses or grain.

A major objective of the present study was to examine the effectiveness of a relatively high rate of application of Mg as kieserite on the concentration of minerals in spring herbage and on the utilization of Mg by ruminants in the period following the onset of grazing, when animals are most prone to hypomagnesemic tetany. A frequently used criterion of mineral status or availability in grazing animals has been the concentration of elements in the serum or plasma. Dutch workers (Committee on Mineral Nutrition, 1973) have stated that concentrations of Mg and Ca in blood are depressed only under severe deficiency conditions, that the concentration of inorganic P in blood cannot be used as a practical criterion and that the best indices of Na and K status are the concentrations of these elements in saliva. A further objective, therefore, was to evaluate a number of mineral components in the blood and saliva as possibly more sensitive indices of the changing mineral status of the animal.

Experimental Procedure

Replicated orchardgrass pastures (.7 ha) were either not treated or treated with kieserite fertilizer at the rate of 2,240 kg/ha (equivalent to 390 kg Mg/ha) in March 1978. N was applied to all pastures (112 kg N/ha as ammonium nitrate) after the kieserite treatment. The pastures were established on a Gilpin silt loam soil, a member of the fine-loamy, mixed, mesic family of Typic Hapludults, with pH in the range of 6.3 to 6.8, adequate P and a high K status as defined by West Virginia University soil testing procedures.

Twenty-four lactating cows (Angus and Hereford) ranging in age from 7 to 12 years were assigned to fertilized and unfertilized pastures on a completely random basis at the beginning of May 1978, when the orchardgrass was at a vegetative stage. The cows had calved within the previous 6 weeks and had been maintained on a good quality orchardgrass hay with a salt and dicalcium phosphate supplement. Jugular blood and salivary samples were collected from all cows between 0900 and 1100 hr on 9 days before and during a 2-week period after the animals were turned to pasture. Saliva was collected from the duct of the parotid gland with Na-free plastic sponges as described by the Committee on Mineral Nutrition (1973).

Serum was removed after blood samples had been kept at 39 C for 4 hours. Heparinized blood was taken for red blood cell (RBC) and plasma preparation. Two milliliters of heparinized blood were transferred to a centrifuge tube and washed three times with 10 ml isotonic saline, and the cells were diluted to 4 ml with distilled water. The hemolyzed preparation was shaken well and frozen. Samples of ultrafiltered serum were prepared with Centrifo membrane cones (Amicon) type CF 25, with retention 25,000 MW (Farese et al., 1970). Five-milliliter samples of serum were centrifuged to yield 2 ml ultrafiltrate. Analysis for Ca and Mg was performed by atomic absorption spectrophotometry, and analysis for Na and K, by emission spectrophotometry, with a Jarrel-Ash model 810. Samples used for Ca and Mg analyses were diluted at 1:50 in .5% lanthanum chloride solution. Samples for Na and K determination were diluted in water. P was determined in serum and saliva by the method of Fiske and Subbarow (1925).

During the 2-week grazing period, herbage from fertilized and unfertilized pastures was fed in digestion and mineral balance trials to mature wether sheep (six per treatment). Grass was clipped twice daily with a rotary mower and fed at a constant intake rate of 6 kg/day (equivalent to 800 to 900 g dry matter). Feces and urine samples were obtained by total collection during a 7-day trial following a 7-day adjustment period. Mg in herbage, feces and urine was determined by atomic absorption, and S in her-
bage and feces, by a Leco induction furnace procedure. Apparent absorption coefficients were calculated for N, K, Mg, Ca, P and S, and apparent retention values (grams per day) were computed for Mg.

Data were evaluated by analysis of variance procedures outlined by Snedecor and Cochran (1967). Data were analyzed as a split-plot design; there was no treatment x replicate interaction, so variation between cows was used as an error term to test replicate and treatment differences.

Results and Discussion

Mineral Composition of Herbage. Data on mineral composition of the orchardgrass are presented in table 1. Kieserite fertilizer applied in March was found to have increased Mg concentration from .22 to .29% (dry matter basis) and S concentration from .20 to .29% when orchardgrass was sampled at a vegetative stage in early May. Both control and fertilized pastures contained more than the NRC (1976)-recommended levels of Mg and S (.18 and .10%, respectively) for lactating beef cows. Kieserite increased (P<.01) the concentration of Fe in orchardgrass, but had no effect on the level of N, K, Ca, P, Mn, Cu, Zn or Na. It is recognized that the change in herbage Mg concentration in response to Mg fertilization depends on soil characteristics and amount and nature of the fertilizer; the change in uptake of Mg from the soluble magnesium sulfate source in orchardgrass in this study was similar to that reported for alfalfa grown on a calcareous silt loam soil in Pennsylvania (Reid et al., 1979), although the increase in S concentration was considerably greater.

Availability of the Mg in herbage may depend as much on the presence and levels of interfering compounds (e.g., K, N, organic acids, long-chain fatty acids) as it does on the actual concentration of Mg. A nomogram relating serum Mg concentrations in grazing cattle to concentrations of K, crude protein and Mg in herbage was prepared by Dutch workers (Committee on Mineral Nutrition, 1973) as an aid in assessing the probability of hypomagnesemic tetany. In these trials, serum Mg concentrations calculated with the nomogram markedly exceeded actual blood concentrations observed in cows on both pasture treatments during the first 3 to 4 days of grazing (figure 1).

Mineral Availability. The apparent absorp-
tion coefficients for N, K, Mg, Ca, P and S and estimated Mg balance of sheep fed unfertilized and fertilized orchardgrass are summarized in table 2. Kieserite fertilization increased (P<.01) the apparent absorption of Mg, as had been observed in previous trials (Reid et al., 1978a) with lambs fed grass hays fertilized with a lower level of kieserite (112 kg Mg/ha). Fertilization also increased the apparent absorption of S (P<.05) but had no effect on the apparent availability of N, Ca or P. The calculated Mg balance of sheep on both pasture treatments was positive, but fertilization with kieserite increased (P<.01) apparent retention from a mean value of .16 g/day for animals on the control treatment to .33 g/day for those on the fertilized herbage. Urinary Mg output as a percentage of Mg intake averaged 14.4 and 15.1% for sheep on the unfertilized and fertilized pastures, respectively, and urinary Mg concentra-

| Item             | DMD, % | N       | K       | Mg       | Ca       | P       | S
|------------------|--------|---------|---------|----------|---------|--------|---
| Unfertilized     | 73.6   | 82.1    | 9.20    | 24.4     | 24.5    | -2     |
| Fertilized       | 73.1   | 82.3    | 9.3     | 36.5     | 23.9    | -11.5  |
| SD               | 1.6    | 2.6     | 0.3     | 1.2      | 0.4     | 0.9    |
| Level of significance | NS | NS     | *       | **       | NS     | NS     |

Table 2. Dry Matter Digestibility, Apparent Absorption of Major Minerals and Retention of Mg by Sheep Fed Orchardgrass

*Mean values ± SD for six sheep per treatment.

aNS = not significant.

*P<.05.

**P<.01.
tions generally exceeded the 100 mg/liter value associated with adequate Mg nutrition of grazing dairy cows (Committee on Mineral Nutrition, 1973).

The apparent absorption coefficients of 24.5 and 36.5% for Mg in unfertilized and kieserite-treated herbage of high N and K status are higher than have generally been reported for spring grass, e.g., a mean value of 17% from a large number of Dutch trials with dairy cows grazing mainly perennial ryegrass (Lolium perenne L.) fertilized with N (Kemp and Geurink, 1978). This may be accounted for in two ways. Previous trials by Powell et al. (1978) demonstrated a higher apparent absorption and apparent retention of Mg by lambs fed cut orchardgrass than by lambs fed other perennial grass species. Further, recent balance trials conducted with several cuttings of alfalfa and orchardgrass hays fed to both mature dry beef cows and mature wether sheep indicate that apparent absorption and retentions of Mg by sheep are higher (P<.01) than values for cattle, with no difference between species for elements such as Ca, S, P and K (Reid, 1980). The sheep, therefore, may not be a suitable experimental animal for assessment of hypomagnesemic tetany potential of forages for cows.

Composition of Blood and Saliva in Cows. Changes in the concentrations of serum Mg, ultrafiltrable Mg and red blood cell (RBC) Mg with fertilizer treatment and with time after the start of grazing are summarized in figure 1. Mg fertilization caused consistent but non-significant increases in serum Mg (1.62 vs 1.73 ± .93 mg/100 ml for control and treated groups, respectively, over all grazing days), ultrafiltrable Mg (1.13 ± 1.21 ± .66 mg/100 ml) and RBC Mg (1.34 ± .44 ± .19 mg/100 ml). Simensen (1970) reported mean concentrations for cattle of 2.05 ± .25 mg/100 ml for serum Mg, and 1.8 ± .78 mg/100 ml for RBC Mg, and cited work of Smith (1957) indicating that 79% of the serum Mg is ultrafiltrable, regardless of the total amount present. Wilson (1964), however, found that, in normal sheep, the proportion of ultrafiltrable Mg varied between 60 and 80%, with a mean of 67%, and suggested that animals suffering from hypomagnesemia with no clinical signs might have a greater proportion of Mg in plasma in the ionic form. Suttle and Field (1969) reported a mean value of 57.2 ± 1.3% for ultrafiltrable Mg in plasma of lactating ewes and concluded that neither Mg nor K intake had an effect on the proportions of bound Mg and Ca in plasma. Results of the present study indicated that the proportion of ultrafiltrable Mg in serum was nearly constant, with mean values of 70% for cows grazing both fertilized and unfertilized pastures, and that the proportion did not change significantly with time after the start of grazing.

Period (days after cows were turned on the pasture) had an effect (P<.01) on serum Mg and ultrafiltrable Mg concentrations, but little effect on RBC Mg. Lowest blood Mg concentrations were observed 1 day after grazing started, with a mean decline of .5 mg/100 ml from the pregrazing sampling. Concentrations increased rapidly during the next 3 to 4 days, to mean values of 2.0 to 2.1 mg/100 ml, with a subsequent decline to pregrazing levels. As in other studies (e.g., Bartlett et al., 1957; Storry, 1961), marked variation was apparent among animals in blood Mg response to a change from winter feeding to grass. This is illustrated in figure 2, which shows typical patterns of serum Mg concentration in individual cows on one replicate of fertilized and unfertilized pastures. While serum Mg concentrations declined to

![Figure 2](https://example.com/figure2.png)

**Figure 2.** Changes in serum Mg concentrations in four cows on one replicate of control and fertilized pastures after the start of grazing. In all replicates, three cows out of 12 on fertilized pastures had serum Mg concentrations <1.0 mg/100 ml after 1 day of grazing, compared with six cows out of 12 on control pastures.
levels of .5 to .6 mg/100 ml at times during the early grazing period, no signs of clinical tetany were observed. If a serum Mg concentration of 1.0 mg/100 ml is accepted as indicative of severe deficiency (Committee on Mineral Nutrition, 1973), 50% of the cows on the unfertilized pastures were Mg-deficient 1 day after commencement of grazing, compared to 25% of the cows on the kieserite-treated herbage.

The effects of fertilization and time on concentrations of serum inorganic P, serum Ca, ultrafiltrable Ca, serum Na and serum K are summarized in figure 3. Fertilization with kieserite resulted in a trend (P>.05) toward higher mean serum P concentrations (4.78 vs 5.26 ± 1.75 mg/100 ml for control and treated groups, respectively), but had no effect on mean concentrations of serum Ca (9.21 vs 9.07 ± 1.15 mg/100 ml), ultrafiltrable Ca (4.24 vs 4.14 ± .63 mg/100 ml), serum Na (139.7 vs 141.6 ± 3.7 meq/liter) or serum K (4.50 vs 4.57 ± .39 meq/liter). The treatment x period effect on concentrations of ultrafiltrable Ca and serum Na was significant, however.

There was a steady decline (P<.05) in serum inorganic P after the second day of grazing for cows on both pasture treatments. A decline in serum P during the early grazing period has been noted in dairy cows by Thompson et al. (1978) and Rayssiguier et al. (1980). Blood Ca concentrations have frequently been found to decrease simultaneously with concentrations of serum Mg during the development of hypomagnesemic tetany in cattle (Simesen, 1970; Fontenot, 1979; Rayssiguier et al., 1980), but, in this study, there were no marked changes in concentration of serum Ca or ultrafiltrable Ca with time, apart from a decline in the level of ultrafiltrable Ca in cows on fertilized pastures during the first 2 days of grazing. There are few reports on the effects of Mg supply on ultrafiltrable Ca; Morris and O'Dell (1969) found no effect of Mg deficiency on ultrafiltrable Ca in plasma of guinea pigs. A frequently cited value for the proportion of ultrafiltrable Ca in plasma is 50% (Wilson, 1964), although Suttle and Field (1969) noted cases of hypomagnesemia in sheep in which values fell to 21.4 and 17.3%. In the present trials, ultrafiltrable Ca in the blood of grazing cows had a mean value of 46%, with a range of 38.9% after 2 days of grazing to 50.6% after 5 days. Earlier studies (e.g., Sjollema, 1930; Bartlett et al., 1957; Todd and Thompson, 1960) showed little immediate or subsequent effect of grazing on concentrations of serum Na or K. The absence of an effect was confirmed in these trials.

Packed cell volume (PCV) was determined on all blood samples. Fertilizer treatment had no effect (P>.05) on PCV (33.4 vs 34.2 ± 4.9% for control and treated groups, respectively). Thompson et al. (1978) reported well-defined seasonal changes in PCV of dairy herds. In this study, PCV was depressed (P<.05) when the cows were first turned to pasture, but there was little change thereafter.

Composition of Saliva of Cows. Mean concentrations of K, Na and inorganic P in saliva from cows grazing kieserite-fertilized and control pastures are shown in figure 4. As would be expected, there was an inverse relationship between concentrations of K and Na, with the total ionic concentration falling generally in the range of 140 to 150 meq/liter. Mg fertilization had no effect (P>.05) on levels of K (14.02 vs
Figure 4. Concentrations of K, Na and P in saliva of cows grazing unfertilized and kieserite-fertilized pastures. Mean values for 12 cows per treatment.

15.35 ± 9.13 meq/liter for control and treated groups, respectively) or Na (129.9 vs 126.6 ± 28.9 meq/liter) in saliva. A treatment × period effect (P<.05) was evident for both K and Na. After 1 to 2 days on pasture, the concentration of K in saliva of cows grazing the fertilized pastures was higher than that in saliva of cows grazing unfertilized grass, a trend accompanied by a depression in salivary Na levels. Period effects (days after initiation of grazing) were significant for both ions. Salivary K concentrations decreased and salivary Na concentrations increased immediately after the cows were turned out on pasture. This finding is at variance with results obtained by Dobson and McDonald (1963) and Dobson et al. (1966) in studies in which sheep were changed from a hay and concentrate diet to pasture fertilized with potassium chloride and ammonium sulfate. Those authors observed an initial increase in salivary K accompanied by a decline in salivary Na, which they related to the decrease in plasma Mg concentration associated with grazing.

The concentration of P in the saliva of sheep has been shown to be related to P concentration in blood (Kay, 1966). In grazing cows, changes in salivary inorganic P concentration initially followed those observed in serum, with an increase on the first day of grazing, a subsequent decline through the fourth day and then a recovery to pregrazing values. Fertilization with kieserite did not affect concentrations of P in saliva (27.77 vs 25.96 ± 12.28 mg/100 ml for control and treated groups, respectively). There was, however, a treatment × period effect (P<.05) on the concentration of P in saliva. Cows on the kieserite-treated pastures showed lower salivary P concentrations after the second day of grazing.

Concentrations of K, Na and inorganic P in saliva, as estimated by the sampling technique, were similar to values for parotid and mixed saliva reported in the literature (Kay, 1966; Bartley, 1976), and the only problem encountered was occasional contamination of the sample by rumen contents. Such samples were discarded. There was no indication from salivary analysis of an abnormal K or Na status of the grazing cows as defined by standards of the Committee on Mineral Nutrition (1973). Salivary concentrations of K and Na appeared to be more responsive to fertilization and period effects than concentrations in blood. These results support the conclusions of the Dutch workers that salivary analysis provides a convenient and simple assay of the K and Na status of grazing animals.

Literature Cited


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