USE OF PASTURE AND ANIMAL SAMPLES AS INDICATORS OF MAGNESIUM STATUS OF SMALL RUMINANTS IN RELATION TO SEASONAL FLUCTUATIONS


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ABSTRACT
A study was conducted to determine Mg status of grazing sheep in the natural and improved pastures in semi-arid region of Pakistan. Pasture samples including soil, forage, feed, water, and animal samples including plasma, milk, faeces and urine were taken from three different classes of sheep, fortnightly during two different seasons of the year for analyses. Results indicated that all the samples except forage and plasma, and urine in non-lactating sheep remained unaffected by seasonal fluctuations. Plasma Mg2+ in all sheep was found to be marginally deficient in both seasons of the year, but soil and forage Mg2+ contents were found to be adequate for the requirements of plants and animals, respectively. Based on this study it was concluded that Mg2+ level of plasma was likely to be deficient which may be a factor for limiting livestock production in this region. Supplementation with fortified mixture containing this element in appropriate proportion with high bio-availability would seem adequate to these animals during both seasons of the year to increase the productivity of sheep at that farm.

Keywords: Seasonal fluctuations, pasture, semiarid, magnesium status, small ruminants.

INTRODUCTION
All living organisms require magnesium (Mg). Deficiencies are uncommon, due to generally adequate concentrations of the element in foods of monogastric animals and humans. The practical importance of Mg in ruminant nutrition is its relationship to the serious metabolic disorder, grass tetany (hypomagnesemia) (Rending and Grunes, 1979; Fontenot et al., 1983; Grunes and Mayland, 1984; Underwood and Suttle, 1999; McDowell, 2003).

Magnesium was first shown by LeRoy in 1924 to be essential for normal growth in animals (Leeson and Summers, 2001). In 1932, Kruse and co-workers produced Mg deficiency in rats and described the specific clinical signs of the deficiency: vasodilation, hyperirritability, convulsions, and death.

Magnesium is abundant in most common feedstuffs, and is present in the animal body at approximately 0.05% of total weight, with about 60 to 70% found in the skeleton, and the remainder in the soft tissue and extracellular fluids. Serum, for example, normally contains Mg at 2 to 4 mg/dl. The concentration of Mg within the cells of the body is higher than that of any other mineral except K (Sell, 1980; Shils, 1997)

Magnesium is excreted in both urine and faeces and secreted in milk. Urine is the major excretory pathway for Mg after absorption (Sell, 1980). Endogenous Mg also reaches the faeces by way of bile, saliva, gastric juices, pancreatic juices, intestinal secretion, and intestinal defoliation. Fecal Mg excretion varies with Mg intake in sheep. A correlation of 0.67 was obtained between dietary and fecal Mg and 0.95 between Mg absorption and urinary excretion (McDowell, 2003). Even though milk is low in Mg, it was the main source of Mg losses from the body in milking cows (Meyer, 1976). Salih et al. (1987) reported Mg in the colostrums of Brahman cows to be 220 ppm and to decline to 61 ppm after 3 months of lactation.

Magnesium has many diverse physiological functions. The Mg in the skeleton is important for the integrity of bones and teeth. It is present mainly as the Mg ion and as Mg(OH)2 held within the hydration shell on the apatite crystal surface. Magnesium is the second most plentiful cation (after K) in intracellular fluids. Although only about 1% of the total Mg is in the extracellular fluid (blood plasma and interstitial fluid), this Mg bathes the body cells and is of great importance. When the Mg in the extracellular fluid declines substantially below normal, the consequences are quite serious (e.g., tetany) (Kemp, 1983; Shils, 1997; McDowell, 2003; Khan, 2003)

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Minimal requirements of Mg for growth of grazing livestock can generally be met by pastures or diets containing 0.10 to 0.15%. A greater concentration, 0.18 to 0.21%, is considered necessary for lactating cows. Magnesium requirements for gestating beef cows have been estimated to be between 7 and 9 g/day, and between 18 and 22 g/day during lactation (Fontenot, 1980). In order to meet the lactation requirement, forages must contain between 0.16 and 0.19% Mg. It appears that Mg required by beef cows is much lower during gestation than during lactation. The minimal dietary requirements depend on the species, the criterion of adequacy employed, the chemical form in which the element is ingested, and the nature of the rest of the diet. It is suggested that sheep were 1.75 times more efficient at absorbing dietary Mg than cattle (Fontenot et al., 1989).

The Mg content of forage plants is normally higher in legumes than in grasses (NRC, 1982). Temperature and light may affect forage Mg concentrations and grass tetany etiology. Overall shading probably reduces forage Mg availability; the incidence of grass tetany is greater when daily radiation levels are low (McDowell, 2003). Magnesium concentrations generally decline as the plant matures, but this lowered concentration is often less dramatic than for many other minerals. Stem tissue contributes appreciably to total plant Mg; that of early maturity stage of growth forms the bulk of plant dry matter. Magnesium concentrations were greater in stems than in leaves of dwarf elephant grass (*Pennisetum purpureum*) (Montalvo et al., 1987).

Grass tetany (or hypomagnesemia) is a complex ruminant metabolic disorder affected by mineral composition of forage species, soil properties, fertilizer practices, season of the year, temperature, animal species, breed, and age. Grass tetany is quite rare for livestock consuming predominantly legumes, as they are generally higher in Mg than grasses. Grass tetany is not an entirely appropriate name because the disorder is not limited to animals receiving grass and is characterized by convulsions rather than tetany. A number of clinical syndromes in cows, sheep, and goats are included in the grass tetany syndrome. Grass tetany is also referred to as lactation tetany, grass staggers, wheat pasture poisoning, winter tetany, and milk tetany in calves (McDowell, 2003).

For all species with a Mg deficiency, concentrations in serum, erythrocytes, and urine are depressed. Increasing dietary Mg for lambs resulted in a linear increase in serum Mg. Peak serum Mg levels were 3.0, 3.2, 4.2, and 5.5 mg/dl for lambs fed 0.2, 0.6, 1.2, and 2.4% Mg, respectively. Bone concentrations of Mg are significantly reduced with a deficiency. This is less pronounced for older ruminants, as they are less able to mobilize Mg than are younger animals. Serum Mg is a good indicator of Mg status of various species, but Mg urinary excretion and erythrocyte concentrations are better indicators. The Mg content of the erythrocytes decreases to about one-half the normal amount during the early phase of depletion, but Mg concentration in serum does not decrease until there is a severe deficiency. In contrast, an excess or a lack of Mg is immediately reflected in daily excretion of Mg in urine; hence, daily urinary excretion is a better criterion of Mg supply than is serum Mg concentration. (Shils, 1996; Judson and McFarlane, 1998).

For grazing ruminants, confirmation of grass tetany is justified only when blood or urine samples are low in Mg. A rough assessment of supply for grazing animals can be obtained from the content of Mg, N, and K in pasture. This approach is more accurate when the pasture is sampled close to the date of grazing. If the dates are more than a week apart, the assessment is unreliable. This method can be used only for grazing cattle, whereas the urine method is reliable on indoor diets as well as pasture (NCMN, 1973).

The factors in the soil which affect mineral uptake by the roots of the plant and the factors which affect mineral availability in different parts of the aerial part of a plant, in the digestive tract of animals and even in the tissues of the animal, need to be investigated to enable the prediction of mineral status of animals to be made from mineral content of soil and plants. The mineral composition of forages varies according to factor, such as plant age, soil, fertilization practice, species, variety, season, and between soil chemistry and mineral composition of native vegetation and farm crops. Despite their importance mineral interactions between soil, plants, and animal in Pakistan has received little attention (Khan, 2003).

As many mineral deficiencies or imbalances in soil and plants have long been held responsible for low production and reproduction problems among livestock, but inadequate information on soil and forage mineral concentrations during different seasons is lacking despite the importance of this semi-arid region to livestock production in Pakistan. Therefore, it is necessary to determine the soil and plant mineral (magnesium) status in view of its importance for grazing livestock and to know if provision of supplements mixture containing magnesium along with forages would improve the Mg status of grazing animals, or if it would cause potentially toxic accumulation of this mineral in animals.

**MATERIALS AND METHODS**

Soil, forage, feed, water, and animal samples were taken from the farm, Livestock Experimental Station located, in southern Punjab, owned by the Govt. of Punjab, Pakistan. These collections were made eight times fortnightly.
during the year (four times both during the summer and winter seasons). Composite soil and forage samples were collected at three sites from the pasture. The five sub samples of soil and forages were taken from the beginning, middle, and end of the pasture.

Each composite soil samples which was derived from five sub-samples taken at a depth of 20cm as described by Sanchez (1976). As with soil samples, each of the composite forage sample came from a five sub-samples of the same predominating forage species that was most frequently grazed by sheep on the farm. Forages were collected after careful observation of sheep grazing pattern. The forage samples were clipped to a height of 3-6 cm, from the ground to simulate the grazing behaviour of animal. Individual forage samples were collected at the same spots from where soil samples were collected. Representative samples of the forages then were placed in polyethylene bags at the laboratory where they were given a rapid wash with tape water followed by a glass-distilled water to remove any soil which was present. Soil and forage samples were placed in clean cloth bags for air drying.

For sampling purpose animals were divided into 3 classes, lactating/non-lactating and male animals respectively, with 10 animals per class. Blood plasma, milk, faeces and urine samples from lactating, plasma, faeces, and urine from non-lactating and plasma and faeces from male sheep were taken at the farm concurrently with the soil and forage samplings.

Blood samples were anaerobically collected by jugular vein puncture with a syringe and needle, then drawn by vacuum into evacuated tubes containing lithium heparine as an anticoagulant, and plasma was separated by centrifugation and was harvested in to polyethylene tubes and frozen at -20°C for subsequent analysis for magnesium. Fecal samples were collected from the rectum of the animals manually and urine samples collected via manual stimulation of the vulva of female animals and a 10ml aliquot was transferred to a polyethylene tubes, acidified with 0.3ml concentrated HCl, and frozen for subsequent analysis (Tucker et al., 1990). The fecal samples were kept in open bags and allowed to dry in sun to constant atmospheric moisture (<30%). Milk samples were collected in 125ml nalgene bottles using the first drawn milk. All lactating animals were sampled shortly after administration of 1ml oxytocin injection to stimulate milk let down. Milk samples were taken in plastic vials and stored frozen until analysis (Fick et al., 1979).

Feed samples consumed by the animals were collected in five replicates for assay of magnesium at each sampling period in cloth bags and were air-dried. Water samples were taken in borosilicate vials from pans fortnightly during both sampling seasons along with other samples in five replicates. The samples of forages, feed, and faeces were dried in an oven at 60°C for 48 hours.

Air and oven dried soil samples were pulverized in a ceramic mortar to pass through a 2mm sieve and were analyzed for Mg concentrations using a Mehlich-1 (Hesse, 1972; Rhue and Kidder, 1983) extraction procedure: 5g of soil were added to 20ml of 0.05 M HCl in 0.025 M H2SO4 and final volume was analyzed.

Water and urine samples were filtered into sterilized plastic beakers, and 1ml aliquots were used to prepare serial dilutions for analysis. Air and oven dried samples of forage, feed and faeces were ground with a Wiley mill to fit through a 1-mm mesh. To prepare samples for estimation of magnesium representative dried and ground samples of about 2g each of forages, feed, and faeces were digested by nitric acid and perchloric acid (3:1) at 250°C until the solution changed to colorless and thick white fumes appeared in the flask. The contents of the flask were washed with pure water and diluted to constant volume. The supernatant obtained from centrifugation was used for analysis (Koh and Judson, 1986, AOAC, 1990; Neathary et al., 1990). Direct dry or wet ashing of plasma and milk was not possible because of high fat, protein and moisture as spattering and swelling might result in loss of sample. Therefore appropriate quantity of each plasma and milk sample were taken into crucible after thawing. To pre digest, the samples were pretreated with 50% HNO3 over an electric heater until smoking ceases to char the majority of organic matter. These samples then were ashed for 6 hours at 550°C in a muffle furnace.

The residues were dissolved in 1% HCl and transferred into a volumetric flask to make up a constant volume of 50ml. Samples were poured into labeled plastic tubes suitable to fit the auto sampler of Atomic absorption spectrophotometer. The samples were diluted to determine individual elements (Mpofu et al, 1999; Nockels et al., 1993; AOAC, 1990; Fick et al., 1979).

All the samples were filtered through Whatman filter paper No. 42 and brought to appropriate volume with double distilled water and stored in polyethylene tubes. Samples were analysed for concentration of Mg by atomic absorption spectrophotometry (Perkin-Elmer Model 5000).

The data were analysed using a split-plot design (Steel and Torrie, 1980). Differences among means were ranked using Duncan’s New Multiple Range Test (Duncan, 1955).

Soil, forage, and plasma magnesium concentrations were compared to established critical values to determine the various categories of deficient levels. The critical level for soils indicates the magnesium concentration below which normal growth and / or mineral composition of forage may be adversely affected. For forage samples, it indicates the lowest requirement of the element or organic constituent to avoid deficiency symptoms in animals.
Plasma critical levels indicate the concentration below which specific signs of deficiency may occur. Interpretation of these critical values was done with caution taking into consideration the management, nutritional, environmental and individual factors that affect the availability, supply and utilization of each nutrient.

RESULTS

PASTURE SAMPLES

Soil
There was no seasonal effect on Mg\(^{2+}\) concentration in soil, whereas effect of sampling time on soil Mg\(^{2+}\) level was significant (Table 1). Average soil extractable Mg\(^{2+}\) in the winter and summer seasons varied considerably at different fortnights. The data showed that during winter, soil Mg\(^{2+}\) decreased with time up to fortnight 3 and almost remained unchanged up to fortnight 4, whereas in summer, there was a consistent decrease in Mg\(^{2+}\) level up to the 3\(^{rd}\) fortnight, while at the 4\(^{th}\) fortnight the Mg\(^{2+}\) level remained unchanged similar to that in winter (Fig. 1a).

Forage plants
There was a marked seasonal or sampling period effect on Mg\(^{2+}\) concentration of different forage species (Table 1). Forage Mg\(^{2+}\) concentration during winter was higher than that in summer, and it showed a lag phase up to fortnight 2 followed by a phase of sharp decrease from 2\(^{nd}\) to 3\(^{rd}\) fortnight, but it remained unchanged up to fortnight 4. In contrast, in summer the forage Mg\(^{2+}\) remained unchanged throughout the season (Fig. 1b).

Water
Analysis of variance of data for Mg\(^{2+}\) concentration in water showed that seasons had no effect on Mg\(^{2+}\) level, whereas sampling time significantly affected it (Table 1). During winter, Mg\(^{2+}\) concentration was maximum at the 2\(^{nd}\) fortnight followed by that at the two last fortnights, In contrast, during summer the Mg\(^{2+}\) level remained unaffected throughout the season. (Fig. 1c).

Feed
A non-significant effect of seasons and significant of fortnights on feed Mg\(^{2+}\) concentration was observed (Table 1). Feed Mg\(^{2+}\) did not vary during winter at different fortnights, but in contrast, during summer the maximum reduction in feed Mg\(^{2+}\) was observed at the 4\(^{th}\) fortnight, whereas the feed Mg\(^{2+}\) at the first three fortnights was almost uniform. (Fig. 1d).

Table 1. Analysis of variance of data for Mg\(^{2+}\) concentration in soil, forage plants, water, and feed at different fortnights during winter and summer season at sheep ranch.

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Degree of freedom df</th>
<th>Mean squares</th>
<th>Degree of freedom df</th>
<th>Mean squares</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Soil</td>
<td>Forage plants</td>
<td>Water</td>
</tr>
<tr>
<td>Season (S)</td>
<td>1</td>
<td>5161.41(^{ns})</td>
<td>265518750.00***</td>
<td>1</td>
</tr>
<tr>
<td>Error</td>
<td>28</td>
<td>4301.88</td>
<td>8147130.95</td>
<td>8</td>
</tr>
<tr>
<td>Fortnight (FN)</td>
<td>3</td>
<td>15051.85***</td>
<td>27492083.33***</td>
<td>3</td>
</tr>
<tr>
<td>S x FN</td>
<td>3</td>
<td>937.72(^{ns})</td>
<td>6868750.00**</td>
<td>3</td>
</tr>
<tr>
<td>Error</td>
<td>84</td>
<td>709.74</td>
<td>6190178.57</td>
<td>24</td>
</tr>
</tbody>
</table>

\(^{ns}\), \(^{*}\), \(^{**}\), \(^{***}\) = Significant at 0.05, 0.01, and 0.001 levels, respectively; \(^{ns}\) = non-significant.
ANIMAL SAMPLES

LACTATING SHEEP

Plasma
Both the seasons and fortnights did not affect Mg$^{2+}$ concentration of plasma (Table 2a). However, the higher level of plasma Mg$^{2+}$ was observed during summer than that during winter. During winter the plasma Mg$^{2+}$ level remained almost uniform at all fortnights (Fig. 2a). While during summer, a consistent increase in plasma Mg$^{2+}$ level was observed with time.

Faeces
The concentration of Mg$^{2+}$ in faeces during both seasons and sampling intervals was not affected significantly (Table 2a). The level of Mg$^{2+}$ in faeces remained unaffected during winter. In summer the maximum fecal Mg$^{2+}$ was found at the 4th fortnight, whereas at the first three fortnights fecal Mg$^{2+}$ was almost same (Fig. 2b).

Urine
No effect of seasons or sampling time was found on urine Mg$^{2+}$ concentration (Table 2a). It remained uniform in winter and summer at the last three consecutive fortnights, but at the 1st fortnight a marked reduction in urine Mg$^{2+}$ was observed during both the seasons (Fig. 2c). The urine Mg$^{2+}$ concentration was higher in winter than that in summer.

Milk
There were no obvious effects of seasons or fortnights on Mg$^{2+}$ level of milk as is evident from the analysis of variance (Table 2a). During winter, Mg$^{2+}$ concentration increased consistently with time, but in contrast, it decreased during summer (Fig. 2d).

NON-LACTATING SHEEP

Plasma
There was marked seasonal and sampling interval effects on plasma Mg$^{2+}$ concentration (Table 2b). Plasma contained significantly higher amount of Mg$^{2+}$ during summer than that during winter. A consistent decrease in Mg$^{2+}$ concentration with time up to fortnight 4 in Mg$^{2+}$ concentration was observed during both seasons (Fig. 2e).

Faeces
Fecal Mg$^{2+}$ level did not show seasonal changes, but it changed significantly at different sampling intervals (Table 2b). A consistent decrease was observed during both seasons with time up to fortnight 4. Although statistically non-significant, the amount of Mg$^{2+}$ excreted via faeces in winter exceeded that in summer (Fig. 2f).

Urine
There was a significant seasonal effect on urine Mg$^{2+}$ level, but the effect of fortnights was non-significant (Table 2b). During winter, the level of Mg$^{2+}$ in urine increased consistently from 1st to 3rd fortnight and thereafter it remained unchanged up to fortnight 4 (Fig. 2g). In contrast, in summer, a sharp decrease from 1st to 2nd fortnight was observed and it did not change thereafter up to fortnight 4.

MALE SHEEP

Plasma
Plasma Mg$^{2+}$ was not affected significantly in different seasons or fortnights (Table 2b). Mg$^{2+}$ concentration of plasma was higher in summer than that in winter. In winter, plasma Mg$^{2+}$ slightly increased with time. Conversely, in summer, plasma Mg$^{2+}$ was first increased sharply up to fortnight 2 and then decreased up to fortnight 4 (Fig. 2h).

Faeces
Non-significant seasonal effect and that of significant of sampling time on Mg$^{2+}$ concentration in faeces was observed (Table 2b). Mg$^{2+}$ concentration in faeces showed a tendency of gradual decrease with time in both seasons. However, Mg$^{2+}$ level in faeces during both seasons was almost same (Fig. 2i).
Table 2a. Analysis of variance of data for Mg$^{2+}$ concentration in blood plasma, faeces, urine, and milk of, lactating sheep at different fortnights during winter and summer seasons.

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Degree of freedom df</th>
<th>Mean squares</th>
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</thead>
<tbody>
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<td></td>
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<td>Plasma</td>
</tr>
<tr>
<td>Season (S)</td>
<td>1</td>
<td>74.7$^{ns}$</td>
</tr>
<tr>
<td>Error</td>
<td>18</td>
<td>20.94</td>
</tr>
<tr>
<td>Fortnight (FN)</td>
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<td>0.92$^{ns}$</td>
</tr>
<tr>
<td>S x FN</td>
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<td>1.18$^{ns}$</td>
</tr>
<tr>
<td>Error</td>
<td>54</td>
<td>0.45</td>
</tr>
</tbody>
</table>

Table 2b. Analysis of variance of data for Mg$^{2+}$ concentration in blood plasma, faeces, and urine of non-lactating, sheep and that of plasma and feces of male sheep at different fortnights during winter and summer seasons.

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Degree of freedom df</th>
<th>Mean squares</th>
</tr>
</thead>
<tbody>
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<td></td>
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<td>Plasma</td>
</tr>
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<td>Season (S)</td>
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<td>113.3$^{**}$</td>
</tr>
<tr>
<td>Error</td>
<td>18</td>
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<td>Fortnight (FN)</td>
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<td>28.9$^{***}$</td>
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<td>S x FN</td>
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<td>5.24$^{***}$</td>
</tr>
<tr>
<td>Error</td>
<td>54</td>
<td>0.29</td>
</tr>
</tbody>
</table>

*, *, **, *** = Significant at 0.05, 0.01 and 0.001 levels respectively; ns = non-significant

DISCUSSION

Extractable soil Mg$^{2+}$ concentrations were almost uniform during both seasons and sufficiently higher than the requirements of plants as reported by Hanlon et al. (1990). Soils above critical level (30-mg/kg) would not be expected to evoke a plant response to Mg$^{2+}$ fertilization (Rhue and Kidder, 1983). Mg$^{2+}$ concentrations observed in soil during this study were almost similar to those reported in Indonesia (Prabowo et al., 1990), Guatemala (Tejada et al., 1987), and Nicaragua (Velasquez-Pereira et al., 1997). These levels of soil Mg$^{2+}$ were much higher than those reported by Espinoza et al. (1991) in central Florida and Tiffany et al. (2000, 2001) in North Florida.

Forage Mg$^{2+}$ concentrations were found to be sufficient for the requirements of grazing animals during winter and summer. Such values are considered to be adequate for normal requirements of animals (Reuter and Robinson, 1997). The mean forage Mg$^{2+}$ concentrations were close to those reported for Nigeria (Ogebe and Ayoade, 1995) and North Florida (Tiffany et al., 2000, 2001). These values are higher than those earlier reported for central Florida (Espinoza et al., 1991) and Nicaragua (Velasquez-Pereira et al., 1997), and lower than those reported by Prabowo et al. (1990) for Indonesia and Cuesta et al. (1993) for North Florida. The Mg$^{2+}$ contents of forage plants are normally higher in legumes than in grasses. Feed and water Mg$^{2+}$ levels were found to be equally important during both seasons to contribute the requirements of grazing animals. Biological availability of different sources of Mg$^{2+}$ for ruminants is considerable. Minimum need of sheep for growth can generally be met by pastures and rations containing 0.10% Mg$^{2+}$. A high proportion 0.18-0.20% is considered necessary for lactation. High dietary levels of protein, K, Ca and P increase the requirement of Mg$^{2+}$ due to their depression of Mg$^{2+}$ absorption in ruminants. It has been observed that the availability of Mg$^{2+}$ ranged from 10 to 25% in forage and from 30-40% in grains and concentrates. Mg$^{2+}$ availability is improved with increasing maturity of grasses and may be decreased by heavy K and N fertilizers. Likewise, usually Mg$^{2+}$ in forage is more available than in pasture (Wilkinson and Stuedemann, 1979).
Fig. 1: Mg$^{2+}$ concentration in (a) soil, (b) forage plants, (c) water, and (d) feed at different fortnights during winter and summer seasons (sheep farm).

(Means with the same letters do not differ significantly at $P<0.05$)

Fig. 2: Mg$^{2+}$ concentration in different sample types of lactating, non-lactating, and male sheep at different fortnights during winter and summer seasons.

(Means with the same letters do not differ significantly at $P<0.05$)
The Mg\textsuperscript{2+} concentration contained in dietary intake was higher in winter than that in summer, but both were in excess of the requirements of animals. Plasma Mg\textsuperscript{2+} levels in all classes of sheep were similar and below the normal level during winter, but in summer almost similar levels of plasma Mg\textsuperscript{2+} were found showing no seasonal or physiological effect in all groups of sheep. The plasma Mg\textsuperscript{2+} levels in summer, however, were on marginal line, which is considered a borderline deficiency. Milk Mg\textsuperscript{2+} contents of the early lactation and late lactation period were almost similar showing no seasonal or lactation period effect. Fecal Mg\textsuperscript{2+} excretion during both seasons was found to be higher in all classes of sheep and in non-lactating sheep only in winter, the possible cause of low level of Mg\textsuperscript{2+} plasma in this particular season. The difference in plasma Mg\textsuperscript{2+} levels was not primarily due to the difference in Mg\textsuperscript{2+} content in the pasture, since in the pasture Mg\textsuperscript{2+} content was higher in winter than that in summer, and the plasma Mg\textsuperscript{2+} level in this season was slightly low. Thus relationships between plasma and that in the pasture were not significant. It is known that high level of K and Ca in the diet interacts with the absorption of Mg\textsuperscript{2+} through the gastrointestinal tract, one of the possible explanations of low Mg\textsuperscript{2+} in plasma found in this study (Chicco et al., 1973).

The effect of seasons and physiological status of animals seemed to be non-significant in this study. Loss of Mg\textsuperscript{2+} through milk in lactating sheep and through faeces in other groups of sheep during winter, when source content was high also seemed to be responsible for low plasma Mg\textsuperscript{2+} during this season. Fecal Mg\textsuperscript{2+} values were considered the reflection of the pasture Mg\textsuperscript{2+} status as found in this study. The kidneys are also involved in maintaining the homoeostatic conditions and utilization of Mg\textsuperscript{2+} in animals and little is excreted when absorption fails to meet requirements. The concentration of the mineral in the urine, however, is markedly affected by changes in water excretion. Urinary concentrations of Mg\textsuperscript{2+} are the preferred tests for assessing Mg\textsuperscript{2+} status of livestock. Dietary Mg\textsuperscript{2+} availability to livestock is affected by other dietary components, which inhibit the Mg\textsuperscript{2+} absorption from the rumen (Judson and McFarlane, 1998). Low Na\textsuperscript{+} content increases dietary Mg\textsuperscript{2+} requirements by elevating the K\textsuperscript{+} concentration in the stomach. In this work, high Na\textsuperscript{+} contents in forage may have inhibited the absorption of Mg\textsuperscript{2+} thereby resulting in lowering plasma Mg\textsuperscript{2+}. Similarly, low level of plasma Mg\textsuperscript{2+} was reported in different classes of sheep in South Africa (McDowell et al., 1984) and in Colombia (Pastrana et al., 1991). According to Rowlands (1980) plasma Mg\textsuperscript{2+} concentration depends mainly on the dietary intake of Mg\textsuperscript{2+}, and plasma Mg\textsuperscript{2+} concentration is controlled to some extent by homoeostatic mechanism (Rojas et al., 1993).

Endogenous Mg\textsuperscript{2+} is primarily excreted via faeces, but urine is also suggested to be the major excretion route for Mg\textsuperscript{2+} absorbed in excess of requirements. Milk is the main source of Mg\textsuperscript{2+} losses from the body of lactating animals. These factors may have been some of the causes of low Mg\textsuperscript{2+} in the plasma of sheep found in this study.

Mg\textsuperscript{2+} concentration in blood plasma does not fall until there is a severe deficiency in the body. In contrast, an excess or lack of Mg\textsuperscript{2+} is immediately reflected in daily excretion of Mg\textsuperscript{2+} in urine. Hence, daily urinary excretion is a better criterion of Mg\textsuperscript{2+} supply than the level of plasma concentration (McDowell, 1985; Judson and McFarlane, 1998).

Although feed or mineral supplements contained very high amounts of Mg\textsuperscript{2+} for complementing the forage Mg\textsuperscript{2+}, these had no obvious effect in raising the plasma Mg\textsuperscript{2+} levels because of the fact that many commercial Mg\textsuperscript{2+} containing mineral supplements are often of little value. Because provision of such supplements to animals during non-susceptible periods is useless as a prophylactic measures. In addition, small additional Mg\textsuperscript{2+} will not provide a depot of readily available Mg\textsuperscript{2+} for emergency use. Thus feeding of Mg\textsuperscript{2+} supplements about a month before the Mg\textsuperscript{2+} deficiency season is necessary (McDowell, 1985; McDowell and Valle, 2000).

Status of Mg\textsuperscript{2+} of soil, forage and animals indicated that all the sheep had marginal deficiency in plasma Mg\textsuperscript{2+} level during both seasons. Feed mineral supplementation was found to have contributed to increase the plasma Mg\textsuperscript{2+} level only during summer but was ineffective during winter. No soil and forage Mg\textsuperscript{2+} deficiency was found during both seasons with respect to requirements of plants or animals.

REFERENCES


MAGNESIUM STATUS OF GRAZING SHEEP IN THE NATURAL AND IMPROVED PASTURE


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