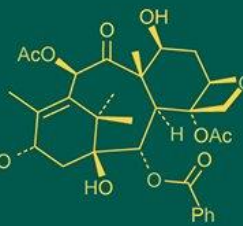
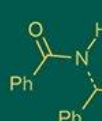


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Seasonal status of magnesium in soil, feed, fodder and blood serum of livestock animals from Solapur district of Maharashtra

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Abstract

Magnesium is a vital mineral for normal body functions, animal health, and productivity. Its availability to livestock depends on soil, feed, and fodder mineral levels, as well as seasonal factors. This study examined how magnesium (Mg) levels vary seasonally in soil, concentrate feed, fodder, and livestock serum across Madha, Mohol, Sangola, and Akkalkote tehsils in Solapur district, Maharashtra. Samples collected during summer, winter, and rainy seasons were analyzed via atomic absorption spectrophotometry. Soil Mg levels stayed above critical thresholds across all four tehsils, with the highest levels typically observed during the rainy season. Mg in feed also tended to increase in the rainy season, with significant differences in Madha, Mohol, and Akkalkote, while Sangola remained relatively stable. Fodder Mg was steady in Madha, Mohol, and Sangola, but Akkalkote saw notable increases from summer to winter and the rainy season. Serum Mg exhibited the most distinct seasonal variation, especially in Sangola and Akkalkote, where rainy-season levels reached 3.99 ± 0.259 and 3.68 ± 0.106 mg/dL, respectively. Overall, the results suggest soil magnesium levels are adequate year-round, but seasonal shifts in feed and fodder influence livestock serum magnesium levels. These findings underscore the importance of region-specific mineral assessments and targeted supplementation during periods of reduced forage mineral availability.

Keywords: Seasons, magnesium, animal health, feed, fodder soil

Introduction

India has a large bovine population and is one of the world's leading milk-producing countries; however, productivity per animal can be limited by inadequate nutrition and mineral imbalances. Magnesium is an important mineral involved in several biochemical and physiological processes, and inadequate magnesium intake can adversely affect animal health, production, and reproductive performance (Maguire and Cowan, 2002; Martens *et al.*, 2018; Pinotti *et al.*, 2021) [9, 10, 15].

Livestock maintained under crop-residue-based feeding systems and grazing conditions may be exposed to mineral deficiencies when diets are not routinely supplemented with mineral mixtures (Ranjan *et al.*, 2012; Mathur *et al.*, 2017) [17, 11]. Mineral deficiencies can interfere with enzymatic and hormonal functions and may consequently affect fertility and productivity (Shukla *et al.*, 2007) [20]. Magnesium supplementation has been associated with improved animal performance and may help prevent hypomagnesemia-related disorders (Zang *et al.*, 2014; Schonewille, 2013; Zelal, 2017) [23, 18, 24].

The magnesium available to grazing and forage-consuming livestock is closely related to the magnesium status of soil and plants. Soil Mg availability is influenced by soil properties, fertilization, moisture and plant uptake (Gransee and Fühns, 2013; Martens *et al.*, 2018) [5, 10]. Seasonal assessment is therefore important because rainfall, soil moisture and plant growth can alter mineral availability. Earlier studies have demonstrated regional variation in the mineral status of soil, feed, fodder and livestock (Choudhary *et al.*, 2015; Panda *et al.*, 2015; Ramesh *et al.*, 2014; Patodkar *et al.*, 2023) [3, 13, 16, 14].

The present study was undertaken to assess the seasonal status of magnesium in soil, feed, fodder and serum of livestock in four tehsils of Solapur district, Maharashtra, and to examine whether the seasonal changes in environmental and dietary magnesium were reflected in the serum mineral profile of animals.

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Materials and Methods

Sample collection

The study was conducted in Solapur district of Maharashtra, India. Samples of soil, concentrate feed, roughage/fodder, and animal serum were collected randomly from Madha, Mohol, Sangola, and Akkalkote tehsils. Soil samples were collected using a pickaxe and trowel and processed for magnesium analysis according to Jackson (1973). Samples of concentrate ingredients and roughages were collected from individual farmer families once during each season. Serum samples were collected from cattle and buffaloes of participating farmers during each seasonal visit and stored at -20°C until analysis.

Sample processing and magnesium estimation

Soil, feed/fodder and serum samples were digested using the procedures described by Francek (1992), Trolson (1969) and Kolmer *et al.* (1951), respectively. Reagent blanks were processed simultaneously. Magnesium concentrations were estimated using an atomic absorption spectrophotometer (ELICO Ltd., Hyderabad, India).

Statistical analysis

The percentage of deficient samples was calculated using the reported critical values for magnesium in soil, feed, fodder and animal serum (McDowell *et al.*, 1984 [25]; McDowell *et al.*, 1993) [12]. Seasonal differences were evaluated using a Completely Randomized Design (CRD), following Snedecor and Cochran (1994), with analysis performed using the Web Agricultural Statistical Package (WASP) of ICAR, Goa.

Results and Discussion

The mean $\pm$ SE values of soil magnesium are presented in Table 1. All recorded values were above the critical soil Mg level of 22 ppm. In Madha, soil Mg increased from 300.75 ± 15.56 ppm in summer to 303.00 ± 13.04 ppm in winter and 324.58 ± 8.40 ppm in the rainy season, with an overall mean of 310.44 ± 11.42 ppm. Mohol showed lower values, increasing from 267.00 ± 6.71 ppm in summer to 281.25 ± 11.62 ppm in winter and 296.50 ± 14.17 ppm during the rainy season, with an overall mean of 281.58 ± 7.07 ppm. Sangola recorded 315.00 ± 7.04 ppm in summer, 305.00 ± 9.65 ppm in winter, and 340.00 ± 8.88 ppm in the rainy season, giving an overall mean of 320.00 ± 6.63 ppm. Akkalkote showed 321.75 ± 20.90 ppm in summer, 306.67 ± 8.90 ppm in winter, and 343.75 ± 14.21 ppm in the rainy season, with an overall mean of 324.06 ± 11.35 ppm. Although the rainy-season values were numerically highest in all four tehsils, the superscripts in Table 1 indicate that seasonal differences were not statistically significant ($P > 0.05$). The absence of deficient soil samples further indicates an adequate soil Mg status in the study area.

The higher numerical values observed during the rainy season may be associated with improved soil moisture and nutrient cycling during periods of rainfall. Similar regional variation in soil mineral status has been reported in Rajasthan, Odisha and Andhra Pradesh (Choudhary *et al.*, 2015; Panda *et al.*, 2015; Ramesh *et al.*, 2014) [3, 13, 16].

Magnesium in feed

Feed Mg showed greater seasonal variation than soil. In Madha, the Mg concentration increased significantly from $0.28 \pm 0.076\%$ in summer to $0.47 \pm 0.074\%$ in winter and

remained $0.47 \pm 0.035\%$ in the rainy season; the overall mean was $0.41 \pm 0.058\%$. In Mohol, values increased from $0.39 \pm 0.040\%$ in summer to $0.46 \pm 0.031\%$ in winter and $0.65 \pm 0.038\%$ in the rainy season, with an overall mean of $0.50 \pm 0.039\%$.

In Sangola, feed Mg remained relatively stable, with values of $0.45 \pm 0.057\%$, $0.48 \pm 0.039\%$ and $0.49 \pm 0.033\%$ during summer, winter and rainy seasons, respectively, and an overall mean of $0.47 \pm 0.043\%$. Akkalkote recorded $0.46 \pm 0.046\%$ in summer, $0.54 \pm 0.090\%$ in winter and $0.60 \pm 0.041\%$ in the rainy season, with an overall mean of $0.53 \pm 0.059\%$. The seasonal superscripts indicate significant increases in Madha, Mohol, and Akkalkote, whereas the seasonal differences in Sangola were not significant.

The higher rainy-season feed Mg concentrations, particularly in Mohol and Akkalkote, may reflect improved mineral availability in locally produced feed resources during the monsoon. The overall feed Mg concentrations remained above the critical level reported for livestock mineral assessment, and no deficient feed samples were recorded. The seasonal pattern is broadly consistent with the importance of dietary mineral supplementation and area-specific mineral management reported in earlier studies (Patodkar *et al.*, 2023; Martens *et al.*, 2018) [14, 10].

Magnesium in fodder

Fodder Mg concentrations were comparatively stable in Madha, Mohol and Sangola. Madha recorded $0.41 \pm 0.047\%$ in summer, $0.45 \pm 0.053\%$ in winter and $0.46 \pm 0.037\%$ in the rainy season, with an overall mean of $0.44 \pm 0.046\%$. Mohol recorded $0.35 \pm 0.049\%$, $0.36 \pm 0.041\%$ and $0.40 \pm 0.056\%$ in summer, winter, and rainy seasons, respectively, with an overall mean of $0.37 \pm 0.051\%$.

Sangola showed values of $0.39 \pm 0.054\%$ in summer, $0.40 \pm 0.066\%$ in winter, and $0.41 \pm 0.064\%$ in the rainy season, with an overall mean of $0.40 \pm 0.061\%$. In these three tehsils, the common superscript indicates that the seasonal differences were not significant. In contrast, Akkalkote showed a clear and significant seasonal increase: $0.30 \pm 0.030\%$ in summer, $0.39 \pm 0.047\%$ in winter, and $0.51 \pm 0.388\%$ in the rainy season, with an overall mean of $0.41 \pm 0.046\%$.

The particularly low summer value in Akkalkote may be related to reduced moisture availability and lower mineral uptake by mature forage. In contrast, improved rainfall and plant growth during the monsoon may enhance mineral accumulation. The absence of deficient fodder samples suggests that, despite seasonal variation, the available fodder generally supplied adequate magnesium. Similar regional differences in mineral content of feeds and fodders have been reported previously (Bhagat *et al.*, 2017; Patodkar *et al.*, 2023) [1, 14].

Serum magnesium

Serum Mg showed the clearest seasonal response among the four sample types. During summer, serum Mg was 3.00 ± 0.054 mg/dL in Madha, 2.62 ± 0.065 mg/dL in Mohol, 2.30 ± 0.048 mg/dL in Sangola, and 3.03 ± 0.113 mg/dL in Akkalkote. Thus, Sangola had the lowest summer value, while Akkalkote and Madha recorded the highest numerical values.

During winter, serum Mg was 3.04 ± 0.052 mg/dL in Madha, 2.64 ± 0.040 mg/dL in Mohol, 2.64 ± 0.106 mg/dL in Sangola, and 3.42 ± 0.115 mg/dL in Akkalkote.

Akkalkote recorded the highest winter value. During the rainy season, serum Mg increased to 3.15 ± 0.057 mg/dL in Madha, 2.69 ± 0.230 mg/dL in Mohol, 3.99 ± 0.259 mg/dL in Sangola, and 3.68 ± 0.106 mg/dL in Akkalkote. The rainy-season values in Sangola and Akkalkote were significantly higher than those recorded in the other seasons, as indicated by the superscripts in Table 1.

The overall means were 3.06 ± 0.020 mg/dL for Madha, 2.66 ± 0.040 mg/dL for Mohol, 2.91 ± 0.175 mg/dL for Sangola, and 3.35 ± 0.117 mg/dL for Akkalkote. Table 2 shows that the overall percentage of deficient serum samples was 1.85%, with the highest deficiency recorded in Sangola (5.56%) and Akkalkote (1.85%). The overall serum values were generally above the critical level, but the presence of

deficient samples indicates that individual animals may still require attention to dietary mineral supply.

The seasonal increase in serum magnesium during the rainy season, especially in Sangola and Akkalkote, likely results from improved availability of Mg in feed and fodder, along with higher dietary intake. This aligns with the idea that mineral levels in soil and forage ultimately influence the mineral status of livestock grazing or fed forage (Martens *et al.*, 2018; Pinotti *et al.*, 2021) [10, 15]. Additionally, regional variations in serum mineral levels in dairy livestock have been observed across different areas of India (Bhagat *et al.*, 2017; Indira and Samuel, 2014; Patodkar *et al.*, 2023) [1, 6, 14].

Table 1: Mean $\pm$ SE levels of magnesium (Mg) in soil, feed, fodder and serum of Solapur district during different seasons

Tehsil	Soil Summer (ppm)	Soil Winter (ppm)	Soil Rainy (ppm)	Soil Overall (ppm)	Feed Summer (%)	Feed Winter (%)	Feed Rainy (%)	Feed Overall (%)
Madha	$300.75^a \pm 15.56$	$303.00^a \pm 13.04$	$324.58^a \pm 8.40$	$310.44^a \pm 11.42$	$0.28^a \pm 0.076$	$0.47^b \pm 0.074$	$0.47^b \pm 0.035$	$0.41^a \pm 0.058$
Mohol	$267.00^a \pm 6.71$	$281.25^a \pm 11.62$	$296.50^a \pm 14.17$	$281.58^a \pm 7.07$	$0.39^a \pm 0.040$	$0.46^a \pm 0.031$	$0.65^b \pm 0.038$	$0.50^b \pm 0.039$
Sangola	$315.00^a \pm 7.04$	$305.00^a \pm 9.65$	$340.00^a \pm 8.88$	$320.00^a \pm 6.63$	$0.45^a \pm 0.057$	$0.48^a \pm 0.039$	$0.49^a \pm 0.033$	$0.47^b \pm 0.043$
Akkalkote	$321.75^a \pm 20.90$	$306.67^a \pm 8.90$	$343.75^a \pm 14.21$	$324.06^a \pm 11.35$	$0.46^a \pm 0.046$	$0.54^b \pm 0.090$	$0.60^b \pm 0.041$	$0.53^b \pm 0.059$
Tehsil	Fodder Summer (%)	Fodder Winter (%)	Fodder Rainy (%)	Fodder Overall (%)	Serum Summer (mg/dL)	Serum Winter (mg/dL)	Serum Rainy (mg/dL)	Serum Overall (mg/dL)
Madha	$0.41^a \pm 0.047$	$0.45^a \pm 0.053$	$0.46^a \pm 0.037$	$0.44^a \pm 0.046$	$3.00^a \pm 0.054$	$3.04^a \pm 0.052$	$3.15^a \pm 0.057$	$3.06^b \pm 0.020$
Mohol	$0.35^a \pm 0.049$	$0.36^a \pm 0.041$	$0.40^a \pm 0.056$	$0.37^a \pm 0.051$	$2.62^a \pm 0.065$	$2.64^a \pm 0.040$	$2.69^a \pm 0.230$	$2.66^b \pm 0.040$
Sangola	$0.39^a \pm 0.054$	$0.40^a \pm 0.066$	$0.41^a \pm 0.064$	$0.40^a \pm 0.061$	$2.30^a \pm 0.048$	$2.64^a \pm 0.106$	$3.99^b \pm 0.259$	$2.91^b \pm 0.175$
Akkalkote	$0.30^a \pm 0.030$	$0.39^b \pm 0.047$	$0.51^c \pm 0.388$	$0.41^a \pm 0.046$	$3.03^a \pm 0.113$	$3.42^b \pm 0.115$	$3.68^c \pm 0.106$	$3.35^a \pm 0.117$

Note: Similar superscripts within rows indicate non-significant differences, whereas different superscripts indicate significant seasonal differences at the 5% level. Values are presented as mean $\pm$ SE.

Table 2: Percent deficient samples (PDS) for magnesium in different tehsils of Solapur district

Parameter	Critical value	Madha	Mohol	Sangola	Akkalkote	Overall
Soil	22 ppm	-	-	-	-	-
Feed	40 ppm	-	-	-	-	-
Fodder	40 ppm	-	-	-	-	-
Serum	0.2 ppm	-	-	5.56	1.85	1.85

Note: Critical values and PDS figures are reproduced from the supplied Solapur manuscript/table. Figures shown as deficient samples are reported as percentages.

Conclusion

The present study demonstrates that magnesium status varied with sample type and season in Solapur district. Soil Mg remained above the critical level in all four tehsils and showed only non-significant seasonal variation, although the highest numerical values were generally observed during the rainy season. Feed Mg showed a stronger seasonal response, with significant increases in Madha, Mohol and Akkalkote. Fodder Mg remained relatively stable in Madha, Mohol and Sangola, whereas Akkalkote showed a significant increase from summer to rainy season. Serum Mg displayed the most evident seasonal response, with particularly high rainy-season values in Sangola and Akkalkote.

Overall, the findings suggest that the magnesium status of the soil and available feed resources in Solapur was generally adequate, but seasonal and tehsil-wise differences can influence the mineral status of individual animals. Periodic mineral profiling and area-specific mineral supplementation may therefore be useful, particularly during periods when forage quality or mineral availability is expected to decline.

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Conflict of Interest

The authors declare no conflicts of interest with any institutions or researchers involved in similar studies.

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