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Seasonal Variation in Manganese Status of Soil, Dietary Components and Grazing Goats

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Abstract

An investigation was conducted in the central region of Punjab, Pakistan to study the relationship of mineral Mn in soil, plant, and animal systems to enable prediction of the nutrient status of three different classes of goats grazing the pasture. Soil, forage, feed, water, and animal samples (blood plasma, milk, faeces, and urine) were collected fortnightly during the winter and summer seasons of 2001. It was found that seasons affected the Mn content of soil, forage, feed, and milk in lactating, plasma in non-lactating and that of faeces in male goats. Forage and fecal Mn in non-lactating goats, and plasma and fecal Mn in male goats were affected by the sampling periods. High Mn concentration was found to be excreted through faeces in non-lactating as compared to other groups of goats. The forage was found to be deficient in Mn concentration for the requirement of animals during summer season despite the high amount of soil Mn during this season. Feed Mn during the winter season was higher than that during summer. Plasma Mn in all classes of goats were above the critical level during both seasons. Consequently, grazing goats at this location need continued mineral supplements containing Mn to prevent deficiency diseases from occurring and support optimum animal productivity particularly during summer when forage Mn concentration is below the requirement of livestock.

Key words: Goats, Grazing, Manganese, Status, Plasma, Milk, Soil, Forage, Pasture

Introduction

Nutritional inadequacies often limit animal production in many countries of the world and in many regions ruminant livestock production is often restricted by mineral deficiencies, toxicities, and imbalances (McDowell, 1985, 1992; Rojas *et al.*, 1993).

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Livestock often do not receive mineral supplements and must depend largely upon forages to meet their nutritional requirements. However, only rarely can forage completely satisfy each of the mineral requirements for grazing animals (McDowell *et al.*, 1993, 1997). The provision of additional minerals beyond their needs is economically wasteful and unnecessary, and confers no added benefits on animals (Underwood, 1981; Rojas *et al.*, 1993).

Minerals are involved in the metabolism and physiology of animals. Like the other trace elements, Mn is closely related with several enzyme systems. It is needed in the body for normal bone structure, reproduction, and for the normal functioning of the central nervous system. Deficiency of Mn during gestation results in poor viability of the offspring; the young of severely deficient animals have skeleton abnormality; many of the Mn deficient offspring are ataxic at birth; showing in-coordination and poor equilibrium and Mn deficiency causes sterility in the male animals (McDowell, 1985, 1997). Concentration of Mn like other minerals in forages is dependent on the soil factors, plant species, yield, pasture management, climate, soil pH (Gomide *et al.*, 1969; McDowell, 1985) drainage conditions, forage maturity, and interaction among minerals (Gomide, 1978; Reid and Horvath, 1980).

Fluctuations in soil atmosphere may affect plant Mn availability (Kabata-Pendias and Pendias, 1992). Low soil pH and high rainfall cause an elevation in soil extractable Mn, and mostly the reduced form of Mn is available for plants. The different seasons affect the availability of Mn to plants and animals, and its solubility increases during the wet seasons. Due to reducing conditions, the leaching of this mineral is known to increase (Velasquez-Pereira *et al.*, 1997). General adequacy of forage Mn to meet animal requirement, even on manganese deficient soil have been reported (Underwood, 1981; McDowell *et al.*, 1989; Vargas *et al.*, 1984). Fertilizations of soils have been found to improve the soil Mn status and pastures in Mn for plants and animal growth (Tiffany *et al.*, 2001).

There is no simple diagnostic test that will permit the early detection of Mn deficiency in animal. Other than forages and soil analysis, animal tissues and fluid are useful but not an entirely reliable indication of Mn deficiency, unless the deficiency is severe (Underwood, 1981). In view of importance of Mn for livestock, the analysis of dietary components as well as animal fluid is important for obtaining Mn status of an area with a view to providing Mn containing supplements to grazing animals. Mn concentrations in different dietary factors and animal fluids provide indication of the Mn intake from different sources consumed by grazing livestock, with the exception of animal reserves. Furthermore fluid analysis of Mn concentration can provide an indication of the sub-clinical presence of deficiencies or toxicities (Underwood, 1981), impacting optimum production. The analysis of mineral source can provide insights into the likely nutrient status of the animal. However, factors such as soil contamination, variation in the availability of ingested minerals and selective grazing may limit the value of analysed mineral concentrations.

Therefore, this study was conducted with the objective to evaluate the manganese status of grazing goats on the basis of Mn concentration in soil, dietary components and animal fluid with respect to seasons of the year to know the correct time for supplementation to improve livestock production and result in a favourable cost-to-benefit ratio.

Materials and Methods

Soil, forage, feed supplement, water, and animal samples including blood, milk, faeces, and urine were collected from the farm "Livestock Experimental Station Rakh Khairewala" located in southern Punjab in Pakistan. The farm is approximately 14000 hectares and comprises about 7000 animals. Soil, forage, feed, and water samples were collected eight times during the year fortnightly (four times during both winter and summer seasons) from the pasture. Within pasture three sites were selected for sampling purpose. At farm, samples from a herd of 30 goats in different physiological conditions and gender with variable degrees of cross breeding (10 lactating, 10 non-lactating, and 10 male goats) were also collected eight times fortnightly similar to pasture samples. The samples from those animals were taken which had been in the pasture for not less than 2 to 3 years prior to sample collection. All the samples except soil were prepared for analysis according to the techniques outlined by Fick *et al.* (1979). While soil Mn analyses were conducted following the method described by Rhue and Kidder (1983), using Mehlich I extractant. Manganese concentrations in all the samples were determined by flame atomic absorption spectrophotometry (Py Unicam Ltd. York Street, Cambridge UK).

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

Results

Pasture Samples

Soil

There was a significant effect of seasons on soil Mn level but no marked effect of fortnights was found (Table 1). The soil contained higher level of Mn^{2+} during summer than that during winter. A sharp decrease from fortnight 1 to 2 followed by an increase at both fortnights 3 and 4 was found during winter. In contrast, during summer, an increase upto fortnight 2 was observed followed by a consistent lag phase upto the last fortnight (Fig. 1a).

Forage plants

A significant effect of seasons and fortnights was found on forage Mn^{2+} concentration (Table-1). High amount of Mn^{2+} was found in forage species sampled during winter than those during summer. A consistent decrease in forage Mn^{2+} was observed with time of sampling during winter, whereas during summer no change in Mn^{2+} was observed with time (Fig. 1b).

Water

Both seasons or fortnights did not show significant effect in relation to water Mn^{2+} level (Table-1). During winter, no significant change in water Mn^{2+} was observed with time, whereas conversely during summer no consistent pattern of increase or decrease in water Mn^{2+} was found (Fig. 1c).

Feed

Analysis of variance of data for feed Mn^{2+} level showed the significant effect of seasons and non-significant of sampling time (Table 1) on Mn^{2+} concentration contained in feed. There was a decrease in feed Mn^{2+} during both seasons from to fortnight I to 2 followed by an increase which persisted upto last fortnight (Fig. 1d). Overall, feed Mn^{2+} level was higher in summer as compared to that in winter.

Animal Samples

Lactating Goats

Plasma

Seasonal or fortnight effect on plasma Mn^{2+} level was found to be non-significant (Table 2a). Almost no significant change in plasma Mn^{2+} in winter or summer at different fortnights was found (Fig. 2a)

Faeces

Mean squares from the analysis of variance of data showed non-significant effects of seasons or fortnights on fecal Mn^{2+} concentration (Table 2a). During winter, a consistent increase and during summer a consistent decrease was observed in fecal Mn2+ in lactating goats (Fig-2b). Generally, excretion of Mn2+ through faeces was higher in winter than that in summer at all fortnights except the first one.

Urine

Urine Mn^{2+} concentration was below the detection limit.

Milk

Significant seasonal effect and non-significant that of fortnights was observed on milk Mn^{2+} level (Table 2a). Non-consistent pattern of increase or decrease in milk Mn^{2+} at different fortnights of sampling was observed during both seasons (Fig. 2d). Generally, milk Mn^{2+} was higher in winter than that in summer.

Non-Lactating Goats

Plasma

There was a non-significant fortnight effect, but a significant seasonal effect on plasma Mn2+ level (Table 2b). A pattern of increase or decrease in Mn2+ level during winter was non-consistent, but in contrast, during summer a progressive decrease in milk Mn^{2+} level was observed with time (Fig. 2e). Higher amount of Mn2+ was present in milk during winter than that during summer.

Faeces

Fortnights affected the fecal Mn^{2+} level significantly unlike the seasons (Table 2b). A consistent increase in fecal Mn^{2+} was observed with sampling time during both seasons (Fig. 2f).

Urine

Urine Mn^{2+} was below the detection limit.

Male Goats

Plasma

Seasons had no effect, but fortnights affected the plasma Mn2+ concentration significantly. A markedly higher Mn2+ was found in winter than that in summer at all fortnights except the second one (Table. 2b). The pattern of increase or decrease in plasma Mn^{2+} level was non-consistent at different fortnights during both seasons (Fig. 2h)

Faeces

There was a non-significant effect of seasons on fecal Mn^{2+} concentration, whereas conversely, the fortnights had a significant effect on it (Table 2b). During both seasons, a consistent increase in fecal Mn^{2+} was found with time of sampling (Fig. 2i). Generally, higher amount of Mn^{2+} was excreted through faeces in summer than that in winter.

Discussion

The minimum dietary Mn^{2+} requirements of ruminants are not precisely known but likely range between 15-25 mg/kg for animals (National Research Council, 1980; Standing Committee on Agriculture, 1990). Mn^{2+} requirements are substantially lower for growth than for optimal reproductive performance and these are increased by high intakes of Ca and P. Although rarely reported for tropical regions, clinical signs suggesting a Mn^{2+} deficiency have been observed in certain regions including Mato Grosso, Brazil (Mendes, 1977).

Dietary Mn^{2+} concentration remains one of the most useful means of detecting possible deficiency in animals so long as the concurrent levels of elements with which Mn^{2+} interacts are also considered. However, in the present investigation, soil Mn^{2+} levels across all samples were found to be high in summer and were above the critical level as suggested by Rhue and Kidder (1983). Similar Mn^{2+} levels and seasonal variation have earlier been reported by Tejada *et al.* (1985) in Guatemala. Manganese is known for its rapid oxidation and reduction under variable soil environments. Oxidizing conditions may reduce Mn^{2+} availability and reducing conditions may increase its availability (Kabata-Pendias and Pendias, 1992). When Mn^{2+} is reduced, its susceptibility to leaching increases. Significant difference was observed in forage Mn^{2+} level in different seasons and forage Mn^{2+} was above the requirement of livestock during winter and below the required level during summer, despite the fact that extractable soil Mn^{2+} was higher during summer. Similar trend in forage Mn^{2+} with respect to seasons had already been reported (Pastrana *et al.*, 1991; Velasquez-Pereira *et al.*, 1997).

Several studies indicated a high tolerance of Mn^{2+} in ruminants (Hansard, 1983). Mineral imbalance typified by excesses of Fe^{2+} and Mn^{2+} may interfere with metabolism of other minerals (Lebdosoekojo *et al.*, 1980). Feed contained higher concentration of Mn^{2+} in summer and lower in winter but was within the range of requirement of goats. While, water Mn^{2+} level was found to have no seasonal effect. The Mn^{2+} content in forage was not sufficient except during winter, although in feed it was within the required range of ruminants during both seasons. Non-consistent relationships between soil and forage Mn^{2+} were found as was already observed by Tejada *et al.* (1985, 1987) in Guatemala.

Plasma Mn^{2+} concentration in non-lactating goats was higher than that in lactating and male goats with no seasonal effect except in non-lactating goats. The non-lactating goats were found to excrete higher Mn^{2+} in their faeces in both seasons as compared to other groups of goats. The plasma Mn^{2+} concentration in all classes of goats was above the critical level (Pamela *et al.*, 2001). It is reported that Mn^{2+} deficiency in animals may occur when diet Mn^{2+} contents are less than the required level (McDowell *et al.*, 1978).

Milk Mn^{2+} contents were significantly affected by season and were within the range of reference value of 0.1 mg/L in winter and below in summer. Manganese absorbed from the gastrointestinal tract is excreted in the faeces. The absorption of ingested Mn^{2+} is generally considered very low and about three or four percent of

Table-1 Analysis of variance of data for Mn^{2+} concentration in soil, forage plants, water, and feed at different fortnights during winter and summer seasons at goat ranch.

Source of variation S.O.V	Degree of freedom df	Mean squares			
		Soil	Forage plants	Water	Feed
Season (S)	1	235.23*	33160.32***	0.0001ns	2250.36**
Error	8	37.10	22.07	0.00004	82.24
Fortnight (FN)	3	10.89ns	123.99***	0.00003ns	90.47 ns
Sx FN	3	68.69*	42.13**	0.00008ns	15.27ns
Error	24	16.75	6.22	0.0001	160.30

*,**,*** = Significant at 0.05, 0.01, and 0.001 levels, respectively.

ns = non-significant.

Table-2a Analysis of variance of data for Mn^{2+} concentration in blood plasma, faeces, urine, and milk of lactating goats at different fortnights during winter and summer seasons.

Source of variation S.O.V	Degree of freedom df	Mean squares			
		Plasma	**Faeces**	**Urine**	**Milk**
Season (S)	1	0.443ns	616.05ns	Below detection limit	0.007 **
Error	18	0.990	425.64		0.0005
Fortnight (FN)	3	0.994ns	12.72 ns		0.0003 ns
S x FN	3	0.033 ns	234.85***		0.0003ns
Error	54	0.047	12.28		0.0002

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

Source of variation S.O.V	Degree of freedom df	Mean squares				
		Non-lactating goats			Male goats	
		Plasma	**Faeces**	**Urine**	**Plasma**	**Faeces**
Season (S)	1	4.27*	143.11ns	Below detection limit	0.10512ns	480.20 **
Error	18	0.72	357.67		0.1664	583.71
Fortnight (FN)	3	0.12ns	202.38 ***		0.0821**	151.48***
S x FN	3	0.60 **	14.81 ns		0.0535 *	4.97 ns
Error	54	0.13	9.46		0.0155	2.28

*,**, *** = Significant at 0.05, 0.01, and 0.001 levels, respectively.

ns = non-significant.

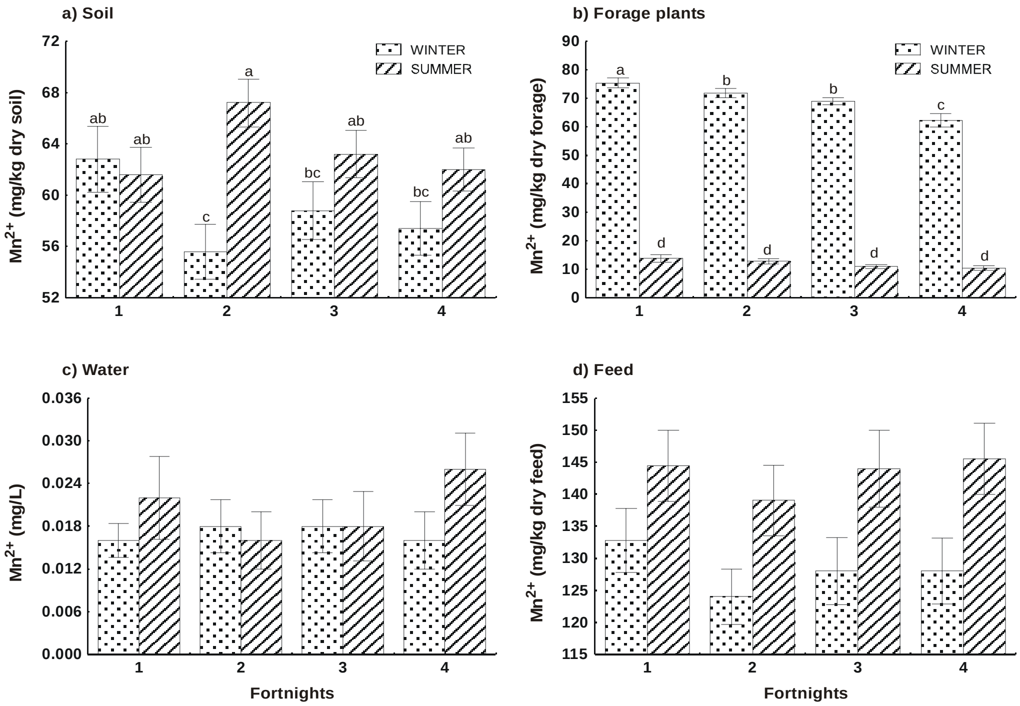

Fig-1: Mn^{2+} concentration in (a) soil, (b) forage plants, (c) water, and (d) feed at different fortnights during winter and summer seasons (goat farm).

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

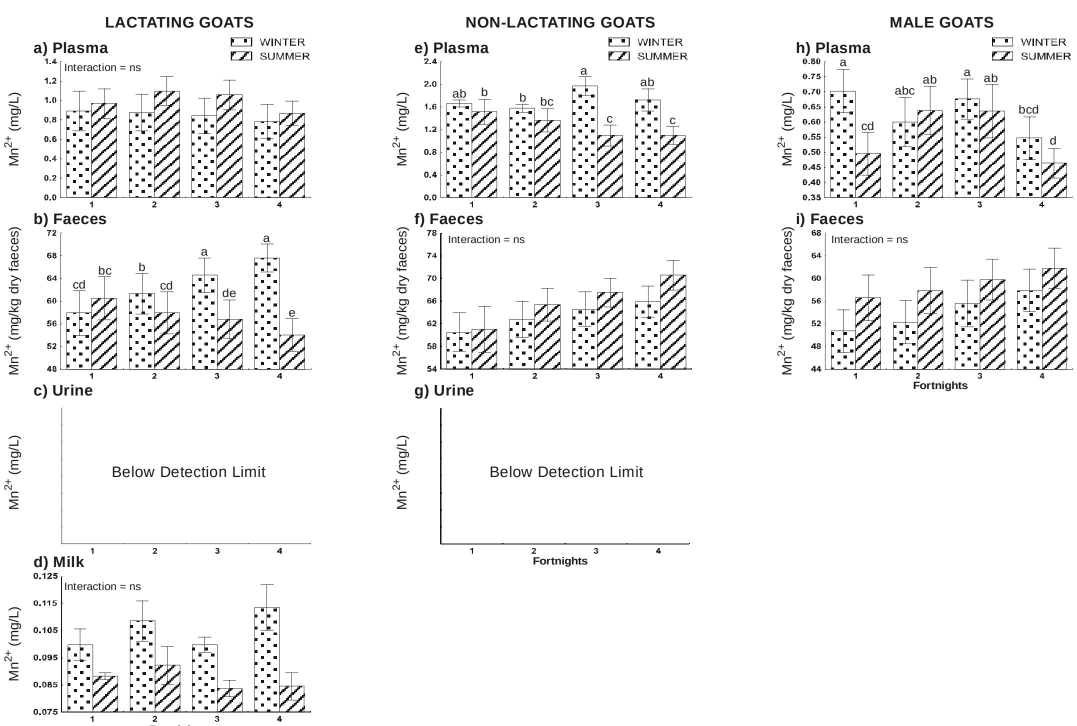

Fig-2: Mn^{2+} concentration in different sample types of lactating, non-lactating, and male goats at different fortnights during winter and summer

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

Mn^{2+} ingested is absorbed and rapidly distributed to many tissues. In this study, low level of Mn^{2+} in plasma slightly above the critical level may be possible explanation of less absorption.

The high level of Mn^{2+} (95-98%) in animals has been reported to be excreted through faeces. In another study, toxic levels of Mn^{2+} administered orally to lambs were excreted exclusively through faeces (Watson *et al.*, 1973). It is concluded that variable excretion and absorption are major homoeostasis mechanisms by which animals maintain normal healthy and performance over the wide range of Mn^{2+} intake under field conditions.

The minimum differences observed in Mn^{2+} plasma level in different classes of goats may be dependent on dietary requirement of Mn^{2+} of different animals under different physiological conditions. Although higher level of Mn^{2+} was found in the feed, it does not mean that maximum level would have been available biologically to the animals. Various factors affect the consumption of mineral mixture like forage type consumed, available protein supplement, individual requirement, salt content of drinking water, palatability of mineral mixture, availability of fresh minerals, and physical form of the feed (McDowell, 1992, 1997). Therefore, the Mn^{2+} content of forage, feed and water found in this study are not the criteria for mineral need of animals. The levels of Ca and P in the diet affect Mn^{2+} requirement and absorption. Ca and P and other unidentified factors are also capable of causing Mn^{2+} deficiency, by increasing Mn^{2+} requirement (Underwood, 1977).

Low forage Mn^{2+} during summer may have been due to soil factors, plant species, stage of maturity, yield, pasture management, and soil pH. While studying mineral composition of tropical grass, a significant year x species x age interaction in Mn^{2+} content was found (Gomide *et al.*, 1969). Poor drainage conditions increase forage Mn^{2+} and increasing soil pH decreases plant availability and uptake of Mn^{2+} (Cox, 1973). Mn^{2+} concentration of forage (40 mg/kg) is considered adequate, 20-40 mg/kg borderline, and less than 20 mg/kg deficient for ruminants. Likewise, soil, water and feed also provide Mn^{2+} towards meeting the animal's requirement.

In this study, it was found that forage contained less than required Mn^{2+} in summer, but no deficiency level in plasma was found, which indicated that feed and water minerals provided Mn^{2+} to complement the forage Mn^{2+}. It is concluded that forage and feed Mn^{2+} contents were sufficient to maintain normal Mn^{2+} plasma level in goats. No seasonal differences were found in plasma Mn^{2+} except in non-lactating goats. The Mn^{2+} status of soil in both seasons was adequate while forage was severely deficient during summer. Plasma Mn^{2+} levels in animals were above the critical levels during both seasons.

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