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Assessment of Iron Status of Different Classes of Goats Grazing the Natural Pasture During Different Seasons

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Abstract

An investigation was conducted in the central region of Punjab, Pakistan to study the relationship of Fe in soil, plant, and animal systems to enable prediction of iron 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. It was found that seasons affected soil, forage, feed, and milk Fe concentrations. The forage was found to be deficient in Fe concentration for the requirement of animals during the summer season. Although plasma Fe did not show seasonal effect and was affected only by the sampling periods in all classes of goats, its values were above the critical level during both seasons. No relation was found between source of Fe and concentration of Fe in excreta. Therefore, it is concluded that feed supplement should be provided to animals particularly during summer to complement the forage Fe for the requirement of grazing livestock in this region.

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

Introduction

Animals mainly depend on forage for their mineral requirements. Forage and soil mineral imbalances are common in different regions of the world, typified by sandy, infertile soils, and forages are frequently low in essential minerals. Many naturally occurring deficiencies in grazing livestock can be related to soil and associated forages (McDowell 1997). Mineral availability to plants is highly dependent on soil pH. Like other minerals Fe is also affected by soil pH fluctuations. Kabata-Pendias and Pendias (1992) found that as the soil pH increases, the availability of Fe to plants decreases. Iron in its reduced form (Fe^{2+}) is available to the plant. As the pH decreases, more Fe^{3+} is reduced to Fe^{2+}; thus Fe becomes more available in acid soils (Velasquez-Pereira *et al.*, 1997).

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The major cause of low plant Fe is the insolubility of Fe^{3+} oxides, the form generally present in most soils (Lindsay, 1984). The inorganic source of Fe applied to soils are converted rapidly to ferrous which are less available to plants; ferrous iron is oxidized to the ferric forms in well aerated soils, especially as soil pH increases (Mortvedt, 1991). Consequently, the Fe deficiency most frequently found on calcareous soils is difficult to control (Morris *et al.*, 1999; Gupta, 1992; McDowell, 1993). However, it is known that poor drainage and aeration of soil increases the availability and uptake of Fe by plants (Grace, 1991).

Among other minerals, Fe plays an important role in the physiology of animals. It is an important component of haemoglobin, myoglobin, cytochromes, and certain enzymes. Iron deficiencies seldom occur in adult animals unless there is a considerable blood loss from parasitism or disease (McDowell, 1997). Iron deficiency may be a problem where ruminants are fed on low quality forage, such as straw. Free-choice complete mineral mixture is an insurance for providing Fe and other minerals where dietary concentrations are unknown or highly variable due to season, location, forage species, and animal potential.

It is important to know micromineral concentrations for new varieties of plants since forage in tropical and subtropical regions is the primary source of minerals for grazing livestock (McDowell, 1992). Different studies have shown an increase in Fe concentrations in tropical forages when yields increase (Espinoza *et al.*, 1991; Santana and McDowell, 1994). Different gross species have been reported to meet the Fe requirements for livestock in certain areas (Arizmendi-Maldonado *et al.*, 2002). The level of Fe in some grasses studied varied from 90 to 1473 mg/kg while the requirement for Fe of all classes of ruminant livestock is below this range (NRC, 1985, 1989, 1996). Indeed, very high concentration of Fe found in many forages could be detrimental to livestock. In addition, it is known that the changes in dietary Fe intake can influence Cu metabolism and cause Cu deficiency in ruminants under practical conditions (Humphries *et al.*, 1985; Youssef *et al.*, 1999).

It is important to determine mineral concentration of soils, forages, feed, water, and animal fluids to estimate the mineral needs of grazing ruminants as well as the time of the year when they are most required. Thus, the purpose of study was to assess the Fe status of selected goat producing region of Pakistan during different seasons of the year to have the knowledge of the correct time for supplementation of this mineral.

Materials and Methods

The study was conducted, during 2000-2002, at the Livestock Experimental unit, located in the southern part of the province of Punjab, Pakistan.

Samples from the animals were collected which had been in the pastures for not less than 1-3 years prior to sample collection. All the animals at the farm had access to feed containing mixture of different minerals, in addition to grazing the improved varieties of forages throughout the year.

Composite forage and soil samples were collected at three sites on goat ranch during two different seasons of the year. Each composite soil sample was derived from five sub-samples taken at a depth of 20 cm as described by Sanchez (1976). Each composite forage sample consisted of five sub-samples of the same forage predominating species that was most frequently grazed by the goats on the farm.

Likewise, feed and drinking water samples being offered to the animals were also collected in five replicates. Blood, milk, faeces, and urine samples were collected from 30 animals of different physiological conditions and gender. Soil samples were processed according to technique set forth by Rhue and Kidder (1983) while the preparation of all the other samples was carried out as described by Fick *et al.*, (1979). The solutions were then analyzed for Fe by atomic absorption spectrophotometry (Pye Unicam Ltd. York street, Cambridge UK).

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

Results and Discussion

Pasture Samples

Soil

Significant seasonal and non-significant sampling period effect was found on soil Fe^{2+} concentration (Table-1). The reduction in soil Fe^{2+} at all fortnights during winter progressed with time. In contrast, during summer the reduction in soil Fe^{2+} was observed at only the last fortnight. (Fig-1a). Overall, soil Fe^{2+} was significantly higher in winter than that in summer.

Forage plants

Seasonal and fortnights effects were found to be significant on forage Fe^{2+} level (Table-1). Forage Fe^{2+} concentration was markedly higher in winter than that in summer. A gradual slight reduction in forage Fe^{2+} level was observed with time during both seasons (Fig-1b).

Water

There was a marked significant effect of fortnights on water Fe^{2+} concentration, whereas the seasons remained ineffective in changing the Fe^{2+} level in water (Table-1). However, the Fe^{2+} in water was found to be higher in winter than that in summer at all four fortnights. A consistent decline in water Fe^{2+} was observed up to fortnight 3 during winter, such consistent decrease in Fe^{2+} level was found from fortnight 2 to onwards (Fig-1c).

Feed

Mean squares from the analysis of variance of the data for feed Fe^{2+} showed significant influence of seasons and fortnights (Table-1). Although feed Fe^{2+} remained unchanged at the first three fortnights during winter, there was a sharp decrease at the 4th fortnight. A similar pattern in feed Fe^{2+} was observed during summer. Overall, feed Fe^{2+} was found to be higher in winter than that in summer (Fig-1d).

Animal Samples

Lactating Goats

Plasma

A non-significant effect of seasons and significant of sampling intervals was observed on plasma Fe^{2+} concentration (Table-2a). During winter, Fe^{2+} level increased from 1st to 2nd fortnight but thereafter it had a decreasing trend up to fortnight 4 (Fig-2a). In contrast, during summer, the plasma Fe^{2+} consistently increased up to 3rd fortnight followed by a sharp decrease at fortnight 4. Overall, the lactating goats contained higher concentration of Fe^{2+} in the blood plasma during winter than that during summer.

Faeces

Non-significant seasonal effect, but significant that of fortnights was observed on fecal Fe^{2+} (Table-2a). During both seasons, a consistent fall in fecal Fe^{2+} level was found with time (Fig-2b). The animals excreted higher amount of Fe^{2+} through faeces during summer than that during winter.

Urine

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

Milk

Milk Fe^{2+} availability was affected significantly by the seasonal change, while the sampling intervals did not affect Fe^{2+} level (Table-2a). The amount of Fe^{2+} in milk was higher in winter than that in summer (Fig-2d). In contrast, in summer no consistent pattern of increase or decrease in milk Fe^{2+} was found

Non-Lactating Goats

Plasma

There was a marked sampling interval effect on plasma Fe^{2+} level, but seasons had no significant effect on it (Table-2b). In winter, the plasma Fe^{2+} level progressively decreased with time (Fig-2e). In contrast, in summer, the plasma Fe^{2+} level was found to be statistically uniform at 1st, 2nd and 4th fortnights. At the 3rd fortnight, the Fe^{2+} level was slightly higher than that at the other three fortnights. Generally, the plasma Fe^{2+} was higher during winter than that during summer.

Faeces

Seasons had no significant effect on fecal Fe^{2+} concentration, but the effect of sampling periods was found to be significant (Table-2b). In winter, a sharp rise in fecal Fe^{2+} at the 2nd fortnight followed by a sharp decrease at fortnights 3 and 4 was observed (Fig-2f). Conversely, in summer, almost the same amount of fecal Fe^{2+} was found to be present at the first two fortnights, and the same was true at the last two fortnights.

Urine

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

Male Goats

Plasma

Plasma Fe^{2+} concentration was affected significantly by the sampling periods, but the effect of seasons was non-significant (Table-2b). In winter, there was a consistent decrease in Fe^{2+} level in plasma with time of sampling (Fig-2h). In summer, a pattern of consistent increase in Fe^{2+} was found up to fortnight 3 followed by a sharp decrease at the 4th fortnight.

Faeces

Significant fortnight effect but non-significant that of seasons was found on fecal Fe^{2+} concentration (Table-2b). A consistent trend of decrease in fecal Fe^{2+} level was found with the increase of sampling time during both seasons (Fig-2i). Generally, excretion of Fe^{2+} through faeces was higher in summer than that in winter.

Discussion

Iron requirements of ruminants are not well established, however, it is known that young animals have high requirements than those in adults. Deficiency is likely to occur in young animals that are fed milk diets and in animals with excessive blood loss or through a rate of degradation of blood cells. However, excess Fe^{2+} can cause Cu^{2+} deficiency (McDowell *et al*., 1993)

Fe^{2+} deficiency is considered rare for grazing livestock due to generally adequate pasture concentrations together with contamination of plants by Fe^{2+} rich soil. Fe^{2+} absorption occurs throughout the gastrointestinal tract including the stomach and colon, but major sites of active absorption are located in the duodenum and jejunum. High dietary levels of phosphorus reduce Fe^{2+} absorption, presumably by the formation of insoluble ferric phosphate and phytate, and higher dietary levels of several other divalent metals, including Cu, Mn. Lead (Pb) and Cd increase Fe^{2+} requirements by competing for absorption sites in the intestinal mucosa (Underwood, 1981). Acidic conditions in the gastrointestinal tract help the absorption. Ascorbic acid also favours iron absorption. Iron is excreted in very less quantities from faeces and urine after absorption.

In this study, mean soil Fe^{2+} concentration fluctuatesd during both seasons. In both seasons ,Fe^{2+} values were generally high, compared to the critical level (Viets and Lindsay, 1973). Adequate soil Fe^{2+} values have already been reported by Mooso (1982) and Merkel *et al*. (1990) from Florida. These results may support the report of McDowell *et al*. (1984) in which it was indicated that Fe^{2+} deficiency is rare in grazing animals due to generally adequate content in soils and forages. However, Becker *et al*. (1965) reported Fe^{2+} deficiency in animals grazing on sandy soils in Florida. Similar seasonal trends in soil Fe^{2+} fluctuation were also reported else where (Tejada *et al*., 1987; Prabowo *et al*., 1990).

Forage Fe^{2+} concentration varied and it was significantly affected by seasonal influence. It was greater than the requirement of ruminants in winter and deficient in summer. Percentage of forage samples, deficient in Fe^{2+} for ruminants requirement (NRC, 1984), was higher during summer and lower during winter. Espinoza *et al*. (1991), found variation in forage Fe^{2+} concentration and higher percentage of Fe^{2+} deficient samples in a study conducted in Florida. Vargas *et al*. (1984) and Tejada *et al*. (1987) in Colombia and Guatemala, respectively did not find Fe^{2+} deficient forage samples. The absorption of Fe^{2+} by plants is not always consistent and is affected by the physiological state of the plant, as well as changing condition of soil and climate (Kabata-Pendias and Pendias, 1992). The generally low forage Fe^{2+} found in summer is in disagreement with the normal soil value found. It may be due to the type of forages deficient in iron below the requirements of animals. Feed Fe^{2+} concentrations showed seasonal effect, being higher in winter than that in summer as reported in the results. Water Fe^{2+} level was almost same during both seasons and both feed and water Fe^{2+} concentration seemed to complement the forage Fe^{2+} level required by the ruminants. The high feed Fe^{2+} did not raise the plasma level. The amount of Fe^{2+} absorbed is related to its need by the animal body, the capacity of the body to excrete Fe^{2+} is very low, therefore, its absorption is controlled by the body requirement. Fe^{2+} is absorbed by mucosal cells of gastrointestinal tract. When these become physiologically saturated, the Fe^{2+} absorption is checked. Therefore, supplementation of Fe^{2+} is much less important than for most other trace minerals. It is most warranted for grazing livestock when forages contain less than 100 mg/kg Fe^{2+} and for if insects or parasites are causing substantial blood loss (McDowell,1997).

Plasma Fe^{2+} concentrations did not differ in different seasons and animal class. The Fe^{2+} was slightly higher in winter than that in summer in all classes of animals (goats). The slight variation in plasma Fe^{2+} may have been due to age effects, gender of the animals, and other factors affecting requirements (Judson and McFarlane, 1998).

The levels of plasma Fe^{2+} were above the critical level suggested by McDowell (1976). These values were much lower than those previously reported by Mpofu *et al*. (1999) and higher than recorded by Merkel *et al*. (1992) and Pastrana *et al*. (1991), who observed similar fluctuations in plasma Fe^{2+} with respect to season.

Fecal Fe^{2+} level did not vary significantly during both seasons in all classes of goats. However, it was higher in summer than that in winter, which was not related to source of Fe^{2+} used. Therefore, fecal Fe^{2+} cannot be considered a good component of pasture status. Urine Fe^{2+} concentrations were found below the detection limit of the instrument used. Milk Fe^{2+} level was significantly higher in winter than that in summer reflecting the dietary intake. These values during both seasons were above the critical level (Pamela *et al*., 2001). Higher value of milk Fe^{2+} has already been reported by Salih *et al*. (1987).

Table-1 Analysis of variance of data for Fe^{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	577.60 **	114490.00***	0.0002 ns	47403.23***
Error	8	29.24	39.69	0.0002	561.60
Fortnight (FN)	3	45.90ns	424.37***	0.00006*	1656.29*
Sx FN	3	17.40ns	8.27ns	0.00002	403.03ns
Error	24	26.67	8.92	0.00002	364.62

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

ns = non-significant.

Table-2a Analysis of variance of data for Fe^{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	1.66 ns	2247.20 ns	Below detection limit	0.071**
Error	18	3.54	3763.34		0.006
Fortnight (FN)	3	0.36**	3495.55***		0.005ns
S x FN	3	0.08 ns	162.83 ns		0.001ns
Error	54	0.08	154.04		0.005

Table- 2b Analysis of variance of data for Fe^{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	2.15ns	1692.80 ns	Below detection limit	0.01 ns	1336.61ns
Error	18	2.90	10680.86		5.23	5042.50
Fortnight (FN)	3	0.45*	14656.63**		1.50***	2422.71***
S x FN	3	0.43*	3972.10 ns		0.74*	23.95ns
Error	54	0.14	2939.27		0.18	18.93

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

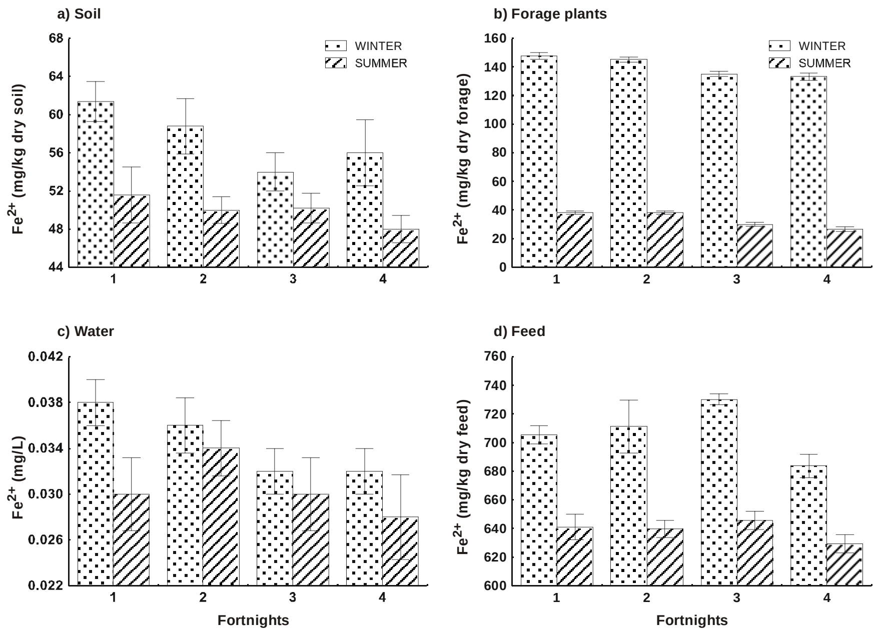

Fig.1: Fe^{2+} concentration in (a) soil, (b) forage plants, (c) water, and (d) feed at different fortnights during winter and summer seasons

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

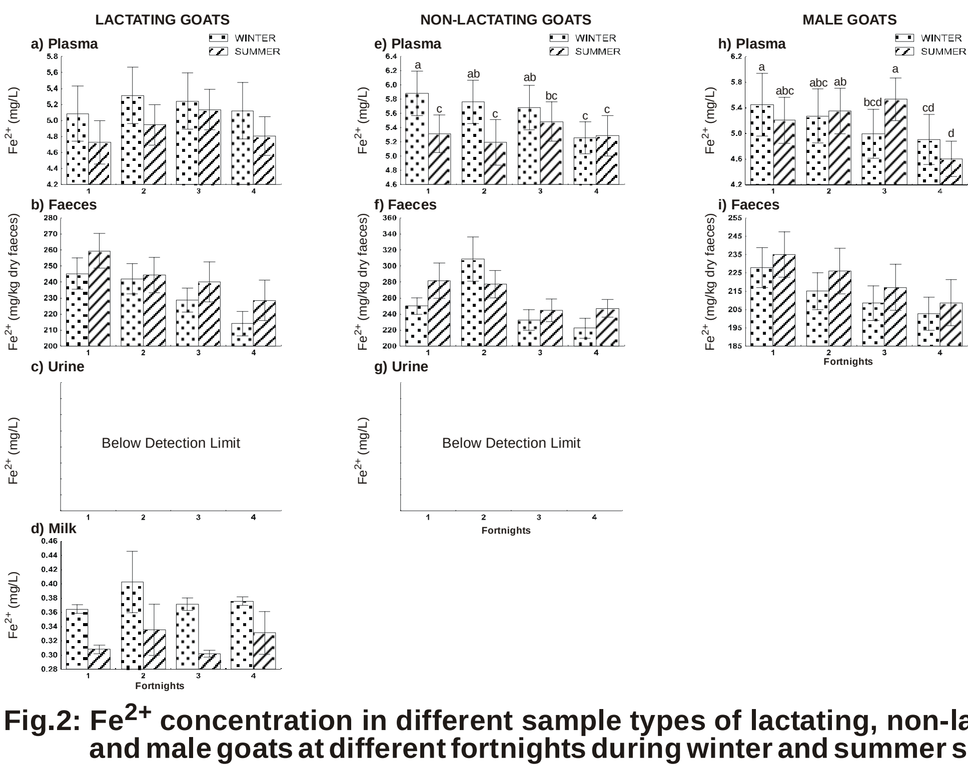

Fig.2: Fe^{2+} concentration in different sample types of lactating, non-lactating, and male goats at different fortnights during winter and summer seasons.

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

The Fe^{2+} absorption is more efficient when body store is low. The amount of Fe^{2+} absorbed is usually a small portion of that ingested, and many dietary factors influence the amount absorbed. The Fe^{2+} absorption is known to occur directly into blood (Thomas, 1970). These may be possible explanations of the adequate level of plasma Fe^{2+} in the present investigation.

The present study has shown that forage Fe^{2+} concentrations were higher in winter than those in summer, but were below the required value for ruminants' need in summer. Based on these findings there are no apparent seasonal or animal class differences in plasma and fecal Fe^{2+} levels, but only milk Fe^{2+} level reflected seasonal influence.

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