Mineral Status of Soils and Forages in Southwestern Punjab-Pakistan: Micro-minerals

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ABSTRACT : This study was conducted to evaluate the trace elemental nutritive values of soil and forages collected from southwestern part of the province of Punjab, Pakistan. Soil and forage samples were collected fortnightly for two seasons. The concentrations of some trace minerals varied greatly among seasons and sampling periods. Seasonal effects were found in all soil micro-minerals except zinc, while forage iron, zinc, and selenium were affected by seasonal changes. Sampling periods effects were observed in all soil minerals and in forage copper, iron, zinc, and manganese only. All soil mineral levels except cobalt and selenium were sufficiently high to meet the requirements of plants for normal growth during both seasons. In contrast, soil Co and Se levels were severely deficient during both seasons and considered inadequate for plant growth. Soil Fe, Zn, Co, and Se levels were higher, and Cu and Mn lower during winter than those during summer. Forage Zn levels during summer were at marginal deficient levels, and in contrast, all other forage micro-minerals were within the required range for ruminants during both seasons. Although forage mico-minerals were within the range required by the ruminants, they were not sufficiently high to prevent the predisposition to various diseases caused by nutrient deficiency. Consequently, grazing animals at this location need continued mineral supplementation of these elements with a mixtures of high bio-availability rather than of high micro-mineral contents to support optimum ruminant productivity. (**Key Words :** Soil, Forage, Mico-minerals, Seasonal Variation, Concentrations, Ruminants)

INTRODUCTION

Ruminant production in different regions of the world are raised under extensive systems or rotational pastures. Under these pasture systems, animals depend on forages to satisfy all of their nutritional requirements. Forage and soil mineral imbalances are common and forages are frequently low in essential trace minerals. Many naturally occurring deficiencies in grazing livestock can be related to soil characteristics (McDowell, 1992; McDowell and Valle, 2000). Mostly the pastures are considered to be adequate in nutritive value (i.e energy and protein) to sustain mature animals, the quality of grasses is often inadequate for growing animals whose physiological demands are higher (Chambliss and Sollenberger, 1991; Tejada et al., 1987; Pastrana et al., 1991).

The mineral composition of forages varies according to various factors such as plant age, soil, fertilization practice, species, variety, seasons, and grazing pressure (Gomide, 1978; Aregheore, 2002). Little relationship has been reported between soil chemistry and mineral composition of native vegetation and farm crops (Reid and Horvath, 1980). There are a number of methods to establish the existence, or likely existence, of specific mineral deficiencies or imbalances for grazing ruminants, in which determination of concentrations and proportions of minerals in dietary components along with clinical, pathological and biochemical examination of animals and appropriate tissues and fluids are commonly used for diagnosis of mineral status of grazing animals (McDowell, 1985; 1992).

Mineral deficiencies may affect production of grazing livestock at pasture in most of the regions of the world, which include those of the major elements Ca, P, Mg, Na, S, and the trace elements Co, Cu, I, Mn, Se, and Zn (Little, 1982; Judson et al., 1987; Judson and McFarlane, 1998; Evitayani et al., 2004; Khan et al., 2005; Goswami et al., 2005).

Excessive intakes of minerals can also commonly have an adverse effect on animal health, the more commonly encountered problems have been associated with excessive intake of the minerals Cu, Mo, Fe, S, Na, K, and F. Signs of

Table 1. Analysis of variance of data for mineral concentrations in soil at different (sampling periods) fortnights during the winter and summer seasons at ruminant ranch

Source of variation	Degree of freedom	Mean squares					
		Copper	Iron	Zinc	Manganese	Cobalt	Selenium
Season (S)	1	04.50***	1,1583.7**	2.54NS	1,672.53***	0.00003***	0.005***
Error	28	0.09	2,049.1	1.75	62.23	0.000036	0.00003
Fortnight (FN)	3	0.35***	1,069.1***	2.75***	884.56***	0.000033***	0.001***
S×FN	3	0.13**	24.9NS	0.15*	15.49NS	0.00005***	0.00001NS
Error	84	0.03	24.7	0.043	20.08	0.000012	0.000024

*, **, *** Significant at 0.05, 0.01, and 0.001 levels, respectively.
NS = Non-significant.

mineral disorders are often non-specific and in cases of marginal deficiencies may go unnoticed by the stock owners. The interpretation of such signs is also difficult if more than one mineral is deficient or the deficiency is associated with other disorders such as increased burdens of gastrointestinal parasites, especially since trace element deficiencies may increase the susceptibility of animals to disease (Suttle and Jones, 1989).

The nutrition of grazing animals is a complicated interaction of soil, plant, and animal. Seasonal variability can markedly affect the dietary intake of minerals as a result of changes in composition, stage of growth and availability of pasture on offer and to changes in the moisture content of the soil (Hannam and Reuter, 1987; Smith and Longeran, 1997; Islam et al., 2003). Research in the area of trace mineral status of soil, feedstuffs and grazing ruminants is limited inspite of their importance in animal nutrition particularly in many developing Asian countries like Pakistan. Hence, there is a need to further investigate the status of trace minerals in soil, and forages in areas rearing ruminants. Mineral supplementation is a least cost input for improvement of livestock production. Nevertheless, mineral supplements should be used only when the mineral requirements of animals cannot be met within the available feed, and only as local conditions dictate. The provision of additional minerals beyond these needs is economically wasteful and unnecessary, and confers no benefits on animals (Underwood, 1981). It is important to determine mineral concentrations of soil, forage, and other feedstuffs used for ruminants to estimate the mineral needs of grazing ruminants, as well as the season of the year when they are most required.

In order to have rapid and economic improvement in ruminant production in Pakistan, as in other developing countries, factors influencing the mineral status of ruminants under grazing conditions must be determined. The purpose of this research was to investigate and evaluate the trace minerals status of soil and forages of a ruminant producing region of Pakistan in order to formulate mineral supplements with high bioavailability of essential trace elements. This information would be used for different ruminant producing regions during winter and summer seasons in Pakistan and other developing Asian countries with similar ecological conditions.

MATERIALS AND METHODS

Pasture description

This investigation was conducted at the Livestock Experimental Station Rakh Khaire-Wala, Lieah district in the southwestern region of the province of Punjab, Pakistan. The ranch comprises 400 ha and receives annual precipitation of 250-750 mm restricted to July and August. Average temperature during the experimental year was between 38±5°C during summer and 15±7°C during winter: relative humidity 48±5% during summer and 80±8% during winter. The soils are sandy and vertisols. The vegetation of the ranch consists of a variety of native and improved forages ranging from grasses, legumes, trees and crops available for grazing animals. Samples of forage were collected from those species that were most frequently grazed by ruminants at this ranch. The forage species collected were: *Medicago sativa, Avena sativa, Trifolium alexandrinum, Hordeum vulgare, Cichorium intybus, Lathyrus odoratus, Chenopodium morale* during winter, and *Cyperus rotandus, Tribulus terrestris, Pennisetum glaucum, Cynodon dactylon, Digitaria decumbens, Cynodon plectostachyum, Panicum milliacum, Sorghum bicolor, Setaria italica* during summer. As mineral status of soil differed from place to place, therefore soil and corresponding forage samples were collected at three different places with 5 replications from each place.

Sample collection and preparation for analysis

Soil and forage samples were collected eight times during the year (4 times during both the winter and summer seasons). Five composite, each of soil and forage samples from each site of the pasture assigned to the experiment were collected after each sampling period during each season. Each composite sample of soil or forage was derived from three sub-samples. Soil samples were obtained using a stainless steel sampling auger to a depth of 15 cm. The sub-samples of forages were collected from an area approximately 70 cm in diameter, and cut to a length of 3-6

Table 2. Micro-mineral concentrations of soil as related to seasons and sampling period (fortnights) at ruminant ranch

Element (mg/kg)	Season	Sampling periods				
		I	II	III	IV	Seasonal means
Cu^{2+}	Winter	1.81±0.0230	1.79±0.024	1.74±0.065	1.69±0.027	1.76±0.014
	Summer	2.39±0.079	2.14±0.058	2.03±0.057	2.04±0.087	2.15±0.040
Fe^{2+}	Winter	103.20±8.04	100.07±7.47	92.73±6.04	89.27±6.31	96.32±3.46
	Summer	81.60±3.93	80.33±4.90	75.53±5.08	69.20±4.57	76.67±2.35
Zn^{2+}	Winter	5.76±0.23	5.63±0.24	5.36±0.23	5.16±0.19	5.48±0.113
	Summer	5.64±0.07	5.31±0.11	4.92±0.14	4.91±0.13	5.19±0.68
Mn^{2+}	Winter	49.00±1.22	44.93±1.40	39.33±1.34	35.93±1.34	42.30±0.92
	Summer	54.49±1.11	53.27±1.89	48.00±1.38	43.33±1.61	49.77±0.94
Co^{2+}	Winter	0.0325±0.0014	0.0313±0.0007	0.0274±0.0005	0.0231±0.0009	0.0286±0.0007
	Summer	0.0272±0.0011	0.0253±0.0007	0.0231±0.0006	0.0234±0.0010	0.0248±0.0005
Se^{2+}	Winter	0.0843±0.0032	0.0819±0.0041	0.0750±0.0018	0.0739±0.0016	0.0788±0.0012
	Summer	0.0727±0.0011	0.0682±0.0013	0.0628±0.0013	0.0597±0.0013	0.0658±0.0009

Means are based on following number of samples of soil (60) during each season.

cm to simulate grazing height. These samples were taken from the same area from which the soil samples were taken. Forage samples were cut using a stainless steel knife and placed in clean cloth bags on the site. Both the soil and forage samples were dried in an oven at 60°C for 48 h and subsequently ground, using a Wiley mill, with a 1-mm stainless steel sieve (forage) or 2-mm sieve for soil. Ground samples were stored in plastic whirlpack sample bags until analysis. Soil minerals were extracted using Mehlich-1 method (0.05 M HCl+0.0125 M H_2SO_4) following Rhue and Kidder (1983). While forage samples were prepared and digested according to the procedures of Fick et al. (1979). Selenium analyses of soil and forages were achieved by fluorometry (Whetter and Ullrey, 1978), while iron, copper, zinc, and manganese concentrations were determined by atomic absorption spectrophotometry on a Perkin-Elmer AAS-5000 (Perkin-Elmer, 1980). An atomic absorption spectrophotometer with graphite furnace and Zeeman background corrector was used to determine soils and forage Co concentrations.

Statistical analysis

The data thus obtained during the study were analyzed by Statistical Analysis System (SAS, 1987). Soil and forage samples were analyzed as split-plot design (Steel and Torrie, 1980), with season as the main plot and sampling periods as the sub-plots Significance levels ranged from 0.05-0.001. Differences between means were ranked using Duncan's New Multiple Range Test (Duncan, 1955).

RESULTS AND DISCUSSION

Soil

Cu^{2+} concentration in soil varied significantly (p<0.001) in different seasons and at different fortnights (p<0.001) (Table 1). The soil Cu^{2+} was significantly higher in summer than that in winter and it remained unchanged at different fortnights during winter. During summer soil Cu^{2+} was higher at the first fortnight than that at the other three fortnights in contrast to winter (Table 2). Soil Cu^{2+} levels during both seasons were above the critical level of 0.3 mg/kg suggested for the normal growth of plants (Rhue and Kidder, 1983). Similar levels of soil Cu^{2+} in winter and summer seasons have earlier been reported in Colombia (Pastrana et al., 1991), Guatemala (Tejada et al., 1987), and Nicaragua (Velasquez-Pereira et al., 1997). Horowitz and Dantas (1973) suggested that soils with less than 0.6-mg/kg of extractable Cu^{2+} are considered deficient for pasture and crops. Based on this, all mean values of soil Cu^{2+} in the present study are not deficient.

The effects of seasons (p<0.05) and fortnights (p<0.01) on soil Fe^{2+} were significant (Table 1). The Fe^{2+} concentration in soil decreased with time of sampling during summer and winter seasons (Table 2). The soil Fe^{2+} in winter was higher as compared to that in summer. Extractable soil Fe^{2+} concentrations during both seasons were above the normal range of 2.5 mg/kg for the growth of plants (Viets and Lindsay, 1973). Similar amounts of soil Fe^{2+} with seasonal fluctuations but higher than the critical level were already reported by various workers, in Guatemala (Tejada et al., 1987), and Colombia and Venezuela (Rojas et al., 1993).

McDowell et al. (1984) reported that Fe^{2+} deficiency is rare in grazing livestock due to a generally adequate content in soils and forages together with contamination of plants by soil. In many parts of the world, under grazing conditions, and annual ingestion of soil can reach 75 kg for sheep and 600 kg for dairy cows (Healy, 1974). Acid soil conditions favour availability and plant uptake of Fe^{2+}. Even plants grown on neutral or slightly alkaline soils often contain quite high levels of Fe^{2+}. These high concentrations of Fe^{2+} in soil found in this study support the idea that Fe^{2+} deficiency cannot be expected to be widespread due to sufficient content of Fe^{2+} in soils and adequate pasture

Table 3. Analysis of variance of data for mineral concentrations in forages at different sampling periods (fortnights) during winter and summer seasons at ruminantt ranch

Source of variation	Degree of freedom	Mean squares					
		Copper	Iron	Zinc	Manganese	Cobalt	Selenium
Season (S)	1	1.04***	55,169.4**	17,731.7***	629.30NS	0.00003NS	0.060***
Error	28	38.02	4,258.8	363.20	1,675.62	0.011	0.004
Fortnight (FN)	3	68.57**	1,414.5**	133.59***	2,377.90***	0.010NS	0.002NS
S×FN	3	9.25ns	33,887.1***	11.3NS	19,404.15**	0.068***	0.014***
Error	84	12.35	1,860.2	27.6	363.34	0.004	0.001

*, **, *** Significant at 0.05, 0.01, and 0.001 levels respectively.
NS = Non-significant.

Table 4. Micro-mineral concentrations of forages as related to seasons and sampling periods fortnights

Element (mg/kg)	Season	Sampling periods				
		I	II	III	IV	Seasonal means
Cu^{2+}	Winter	25.69±2.73	22.45±2.26	18.65±1.66	15.08±1.77	20.42±2.60
	Summer	14.90±0.87	12.40±0.69	11.89±1.08	10.91±1.40	12.53±0.55
Fe^{2+}	Winter	201.73±17.32	191.07±15.25	130.53±7.85	126.27±8.04	162.40±7.60
	Summer	98.13±17.15	92.53±15.44	146.47±7.74	140.93±7.79	119.52±6.98
Zn^{2+}	Winter	52.087±4.32	47.33±3.94	50.20±2.063	47.67±2.51	49.32±1.64
	Summer	26.27±2.67	22.93±1.78	27.37±1.79	23.47±1.25	25.01±0.98
Mn^{2+}	Winter	87.44±9.96	82.52±9.81	56.40±4.26	55.67±3.93	70.51±4.15
	Summer	36.60±6.68	36.00±6.03	99.07±5.61	91.47±5.22	62.78±4.81
Co^{2+}	Winter	0.212±0.019	0.178±0.011	0.144±0.006	0.135±0.005	0.167±0.007
	Summer	0.114±0.005	0.116±0.004	0.237±0.042	0.206±0.032	0.178±0.015
Se^{2+}	Winter	0.173.60±0.021	0.163±0.022	0.115±0.003	0.117±0.004	0.141±0.008
	Summer	0.087±0.007	0.083±0.004	0.106±0.004	0.111±0.004	0.097±0.003

Means are based on 60 forage samples for each element.

conditions (Cox, 1973).

There was not a significant effect of seasons on soil Zn^{2+} concentration (p<0.05), but in contrast, fortnights affected in significantly (p<0.001) (Table 1). In both seasons there was a sharp depression in Zn^{2+} level up to 3rd fortnight in summer and up to the last fortnight in winter. The Zn^{2+} level in soil at the last two fortnights of summer and at the first two fortnights of winter was statistically equal. However, the soil Zn^{2+} was slightly higher in winter than that in summer, particularly at the end of the season (Table 2). Extractable soil Zn^{2+} concentrations were adequate for normal plant growth during both seasons of the year. These values fall within the range of those reported by Tiffany et al. (2001) and Tejada et al. (1987, 1985). These were higher than those found in north Florida by Cuesta et al. (1993) in central Florida by Espinoza et al. (1991) and in Venezuela (Rojas et al., 1993) and lower than those reported by Ogebe et al. (1995) in Nicaragua and Prabowo et al. (1991) in Indonesia. These extractable soil Zn^{2+} concentrations above the critical level of 1mg/kg provide adequate Zn^{2+} for plant growth (Rhue and Kidder, 1983).

Soil Co^{2+} concentration was affected significantly (p<0.001) by seasons or sampling periods (Table 1). A higher level of soil Co^{2+} was observed during winter than that during summer, its level decreased consistently from fortnight 1 to fortnight 4 during winter and up to fortnight 3

during summer, while it decreased sharply at the fortnight 4 during this season (Table 2).

In the present study, mean extractable soil Co^{2+} concentration was severely deficient in view of the critical level of 0.1 mg/kg (Kubota, 1968). These soil Co^{2+} values were not adequate compared to the requirement of plant growth. Similar low level of soil Co^{2+} has earlier been reported (McDowell et al., 1989).

Mn^{2+} concentration in soil varied significantly due to the seasons and sampling periods (p<0.001) (Table 1). A sharp decrease in Mn^{2+} concentration of soil was observed during both winter and summer seasons (Table 2). Generally, soil Mn^{2+} concentration was higher during summer than that in winter. Although there was a significant seasonal variation in soil Mn^{2+} concentration, it was adequate for normal plant growth (5 mg/kg) during both seasons (Rhue and Kidder, 1980). High soil Mn^{2+} in summer than in winter was similar to the observations of Tejada et al. (1987) in Guatemala and Pastrana et al. (1991) in Colombia. These values were higher than those reported by Prabowo et al. (1991) in Indonesia and Rojas et al. (1993) in Venezuela.

Significant seasonal and sampling interval effects (p<0.001) were found on soil Se^{2+} concentration (Table 1). Se^{2+} concentration was higher in winter than that in summer with a tendency for a gradual decrease with time during both seasons (Table 2). In the present study, the soil Se^{2+}

levels were deficient for the requirement of plants during both seasons of the year. Soil Se^{2+} levels during winter and summer were similar to those found by Cuesta et al. (1993) in north Florida and lower than those reported by Pastrana et al. (1991) in Colombia, Khan (2003) in Pakistan and by Rojas et al. (1993) in Venezuela, and higher than the values reported in Florida (Merkel et al., 1990).

Forage plants

Considerable variation in forage Cu^{2+} was observed at sampling intervals (p<0.01) accompanied with a significant seasonal effect (p<0.001) (Table 3). A consistent decrease was observed in forage Cu^{2+} level during both seasons from fortnight 1 to fortnight 4. A higher concentration of Cu^{2+} in forages was found at 1st fortnight during both seasons than those at the last three fortnights. Overall, forage Cu^{2+} concentration was markedly higher in winter than that in summer (Table 4).

In the present study, forage Cu^{2+} level differed significantly during winter and summer. In winter, it was considerably high in the forage plants as compared to that in summer.

Forage Cu^{2+} concentrations were found to be sufficiently high to meet the demand of animals (8 mg/kg) during both seasons (NRC, 1985). The forage Cu^{2+} had no relationship with soil Cu^{2+} levels during both seasons. Forage Cu^{2+} values found in this study were not sufficiently higher, but were within the range and higher than those reported previously in north Florida (Tiffany et al., 2001), Venezuela (Rojas et al., 1993), and central Florida (Kumagai et al., 1990; Espinoza et al., 1991).

These values were similar to those reported for Indonesia (Prabowo et al., 1990) and lower than those reported by Tejada et al. (1985, 1987) in Guatemala. Low forage Cu^{2+} in this study may have been due to its interaction with other elements in soil. McDowell et al. (1993) reported that Cu^{2+} interacts strongly with trace minerals and macro minerals for absorption by the plants. Fe^{2+} and Ca^{2+} are some of the elements that could have had an effect on the absorption of Cu^{2+}, because the concentrations of these elements were very high, as observed in this work. Ca in the form of carbonate precipitates Cu^{2+}, making it unavailable for the plants. In addition, the content of this element often is inversely related to increasing plant maturity, possibly one of the causes of low levels of Cu^{2+} in forage (McDowell et al., 1983; Tudsri and Kaewkunya, 2002).

It has been widely assumed that forages are much more variable than grains. Undoubtedly, this is true for energy and protein. However, the research of Adams (1975) suggests that this may not be the case for the trace elements. When comparing the percentage coefficient of variation for copper, iron, manganese, and zinc, the statistical means for forages were 57, 68, 75 and 63% respectively. The same values for corn were 62, 83, 116 and 39%, respectively. Coefficients of variation were greater for corn than forages for all minerals except zinc. It is true that grains generally have lower concentrations of the trace elements than forages. Consequently, smaller changes in actual amount may appear as a larger coefficient of variation.

The copper was first recognized as an essential nutrient for animals. Today, copper deficiency is known to cause anemia, diarrhea, bone disorders, neonatal ataxia, changes in hair and wool pigmentation, infertility, cardiovascular disorders, impaired glucose and lipid metabolism and a depressed immune system (Davis and Mertz, 1987; Manyayu et al., 2003). Copper is a key component of many enzyme systems which when impaired can directly or indirectly cause many of the symptoms of copper deficiency. Dietary copper requirements vary greatly among species. The recommended levels for one species may cause toxicity in another. For example, 10 ppm is the NRC recommended level for dairy cattle, but under certain conditions 10 ppm can cause toxicity in sheep (Church and Pond, 1988).

Forage Fe^{2+} concentration varied significantly at different fortnights and seasons (p<0.01) (Table 3). In both winter and summer, the forage Fe^{2+} level remained unchanged at the 1st to 2nd fortnights, but a considerable reduction in Fe^{2+} level was observed at the last consecutive fortnights. Forage Fe^{2+} concentration was higher in winter than that in summer (Table 4).

Forage Fe^{2+} levels during both seasons were sufficient for the requirements (50 mg/kg) of ruminants for optimal performance (McDowell, 1985). These levels of forage Fe^{2+} in the present study may support the reports of various researches who found similar higher concentrations of Fe^{2+} with similar seasonal changes, being higher in winter than that in summer, in Guatemala (Tejada et al., 1987), North Florida (Cuesta et al., 1993), Nicaragua (Velasquez-Pereira et al., 1997), Pakistan (Khan, 2003), and Indonesia (Prabowo et al., 1991). The generally high forage Fe^{2+} found in this study is an agreement with the higher soil Fe^{2+} value. This coincides with zero incidence of deficiency in soil samples.

According to Kabata-Pendiaus and Pendias (1992) the changing conditions of soil and climate as well as physiological state of plants affect the Fe^{2+} absorption by the plants. The soil and forage Fe^{2+} concentrations showed a positive association with each other being higher in winter than that in summer in soil and forage, respectively. During summer the total Fe^{2+} contents of forages were slightly higher than those during winter. However, its availability was found to be dependent on many dietary interactions.

The forage Zn^{2+} concentration varied significantly during different seasons and sampling intervals (p<0.001) (Table 3). The forage Zn^{2+} in winter at all fortnights of

sampling was higher than that in summer (Table 4). However, the pattern of increases or decreases in forage Zn^{2+} level at different fortnights was non-consistent.

Forage Zn^{2+} concentration was also found above the requirements of ruminants but only in winter. However, the level in summer was considered slightly deficient for growing and lactating animals (Reuter and Robinson, 1997). Almost similar results were reported by Prabowo et al. (1991) in South Sulawesi, Indonesia and Tiffany et al. (2001) in North Florida.

A number of factors including soil, plant species, pasture management, and climate, may affect the likelihood of Zn^{2+} deficiency in ruminants. Cox (1973) reported the low level of Zn^{2+} in soil and plants. Plant maturity has also been reported to affect Zn^{2+} concentration of forage and it also depends upon the tissue type of plants (Underwood, 1981; Kabata-Pendias and Pendias, 1992; Serra et al., 1997; Narullah et al., 2003).

Overall, total Zn^{2+} level contained in all sources was higher in summer than that in winter, and a positive association was found between soils and forage Zn^{2+} levels during different seasons.

Considerable fluctuations in Mn^{2+} concentration occurred with time in both seasons. The seasonal effect was not significant ($p>0.05$), but the effect of fortnight was significant ($p<0.001$) on forage Mn^{2+} (Table 3). High Mn^{2+} concentration was recorded at the first two fortnights of winter and at the last two fortnights of summer, but the reverse was true at the other fortnights of both seasons, where Mn^{2+} concentration was very low (Table 4).

Forage Mn^{2+} levels were above the critical level during both seasons and were sufficient to meet the requirements of animals. Similar levels of forage Mn^{2+} with seasonal fluctuations have already been reported in Nicaragua (Velasquez-Pereira et al., 1997) with no seasonal changes in Indonesia (Prabowo et al., 1991) and in Guatemala (Tejada et al., 1987). Low Co^{2+} concentration of soil was also a possible explanation of high level of Mn^{2+} in forage as these elements antagonize in the soil (McKenzie, 1967, 1975). On the farm, mean forage Mn^{2+} concentrations were although high, they were below the maximum tolerable levels (NRC, 1985). The Mn^{2+} levels of sources were higher in summer than those in winter.

Analysis of variance of the data for forage Co^{2+} concentration revealed that both seasons and sampling periods had nonsignificant effects ($p>0.05$) on its concentration (Table 3). However, slightly higher values of forage Co^{2+} were found in summer than that in winter. During winter, the forage Co^{2+} level decreased consistently from 1st to 4th fortnights of sampling, while during summer its concentration decreased up to fortnight 3, but at fortnight 4 it decreased sharply (Table 4). During summer, no consistent pattern of increase or decrease in forage Co^{2+}

with time was found.

Forage Co^{2+} levels were deficient for ruminants during both seasons, because these were lower than the critical level (NRC, 1980). Similar Co^{2+} deficient forages were found in Nicaragua (Velasquez-Pereira et al., 1997), in Florida, USA (Espinoza et al., 1991) in Pakistan (Khan, 2003). Rojas et al. (1993) found marginal to deficient Co^{2+} level. Tejada et al. (1987) did not find differences in forage Co^{2+} concentrations among different regions in Guatemala, but the forage Co^{2+} level was higher than the critical values and also than the values reported in this work. It was observed in this study that forage Co^{2+} was deficient during both seasons, but was slightly higher than that in soil. Mtimuni (1982) suggested that there is readily available Co^{2+} in soil for plant growth even on Co^{2+} deficient soil. Similarly, Reid and Horvath (1980) illustrated that the level of Co^{2+} in the soil does not necessarily indicate its availability to plants.

Co^{2+} is often the most severe mineral deficiency of grazing livestock with the possible exception of P and Cu (McDowell et al., 1984). Co^{2+} uptake by plants is dependent on Co^{2+} and Mn^{+2} concentration in soils. High soil Mn^{2+} depresses uptake of Co^{2+} in forages. In the present study, high levels of Mn^{2+} were found in soil, which could have led to reduce Co^{2+} absorption by plants and subsequently, low levels in plant tissues. According to McKenzie (1967, 1975), the soils with high level of manganese oxide strongly bind free soil Co^{2+} to their surfaces leading to low availability of Co^{2+} to plants.

Analysis of variance of data for forage Se^{2+} concentration showed significant seasonal effects ($p<0.001$), but non-significant effect of fortnights ($p>0.05$) (Table 3). There was a significant difference between the first two and the last two fortnights of winter in relation to forage Se^{2+} level. The Se^{2+} concentration was higher at the first two fortnights of winter than that at the last two fortnights. In contrast, during summer the level of forage Se^{2+} was lower at the first two fortnights than that at the last two fortnights (Table 4).

Forage Se^{2+} concentration was not sufficiently high during winter, whereas during summer these were adequate for the normal requirement of animals. The Se^{2+} contents of forage and feed collectively were not different significantly, and were slightly higher in winter than those in summer. There was some positive association between soil and forage Se^{2+} contents found during both seasons. Mean forage Se^{2+} concentrations found in this study were similar to those reported for Guatemala (Tejada et al., 1987) with similar seasonal fluctuations as well as for Colombia (Pastrana et al., 1991), Pakistan (Khan, 2003), and Indonesia (Prabowo et al., 1991). Underwood (1977) stated that the differences in Se^{2+} concentrations between accumulator and non-accumulator plants are marked, but

differences among non-accumulator plants may be minor. It appeared that the site of the farm having sheep population was the region with high Se^{2+} deficiency problem particularly in summer when forage contained Se^{2+} on borderline deficient levels.

Conclusion

Soils and forages collected fortnightly for two seasons from southwestern Punjab, Pakistan were found to contain low micro-mineral contents at marginal levels for the requirements of forages and ruminants respectively, particularly at the end of the season. Seasonal as well as sampling periods effects were found in most of the soil and forage micro-minerals in this study. Mostly higher mineral contents were found during winter than those during summer from both soils and forages, and generally there was a trend of decrease in forage micro-minerals with time of sampling parallel to the advancing maturity suggesting the need of these minerals supplementation to ruminants at the end of seasons. Results of the study also indicated very low and non-existing relationships, therefore soil analyses are not of great importance in the assessment of available micro-mineral supplies to grazing ruminants. Based on soil and forage analyses, it is concluded that micro-minerals are needed for supplementation of grazing ruminants during the summer season particularly and at the end of both seasons generally when there is fall of micro-minerals profile of different forages at this specific region of Pakistan. These results would have application to the remaining Asian countries as well as other countries with regions of similar soils and climate.

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