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EVALUATION OF VARIATION IN SOIL AND FORAGE MICRO-MINERAL CONCENTRATIONS IN A SEMIARID REGION OF PAKISTAN

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Abstract

An investigation was conducted to evaluate the micro-mineral status of pasture having high population of small ruminants in Punjab, Pakistan. Soil and forage samples were collected fortnightly for two seasons. It was found that sampling period affected soil Cu^{2+}, Zn^{2+} and Se^{2+} while all forage minerals except Se^{2+} were affected by sampling times. Seasonal effects were observed in soil Fe^{2+}, Mn^{2+} and Se^{2+}, and forage Cu^{2+}, Fe^{2+}, Zn^{2+}, Mn^{2+} and Se^{2+}. All soil mineral levels except Co^{2+} and Se^{2+} were found to be above the critical levels and likely to be adequate for normal growth of plants growing therein, whereas soil Co^{2+} and Se^{2+} were in severe deficient levels during both seasons for the normal plant growth. The levels of Fe^{2+}, Zn^{2+}, Co^{2+}, and Se^{2+} in soil were higher, whereas those of Cu^{2+} and Mn^{2+} were lower during winter than those during summer. Forages contained marginal deficient level of Co^{2+} during winter, those of Cu^{2+} and Se^{2+} during the summer. Moderate deficient levels of Fe^{2+} and severe deficient level of Zn^{2+}, Mn^{2+} and Co^{2+} were found during the summer. Forage Co^{2+}, Fe^{2+}, Zn^{2+}, Mn^{2+} and Se^{2+} during winter were found to be adequate for the requirements of ruminants. Consequently, grazing animals at this location need continued mineral supplementation of these elements to prevent diseases caused by nutrient deficiency, and to support optimum animal productivity.

Introduction

Under pasture systems, animals depend on forages to satisfy all of their nutritional requirements. Unfortunately, forages often do not provide all of the needed minerals, which animal require throughout the year. Many incidences of mineral inadequacies in forages and soils have been reported which are principal causes of reproduction failure and low production rate (McDowell, 1985; McDowell *et al.*, 1993; Vargas & McDowell, 1997). Mineral deficiencies likely to affect production of grazing livestock at pasture in most of the regions of the world 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).

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 mineral disorders are often non-specific and in cases of marginal deficiencies may go unnoticed by the stock owners. The interpretation of such sign 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 & Jones, 1989).

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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 and to changes in the moisture content of the soil (Hannam *et al.*, 1980; Smith & Longeran, 1997). Pasture and soil tests are not perceived to be the initial tools for diagnosis of animal deficiencies. If pasture samples are taken in association with the animal samples an explanation of the predisposing pasture conditions may be assessed and subsequent routine plant analyses may be able to predict the variable incidence of the mineral problems. The advantage of this is the ease and comparative lower cost of plant tissue analysis when compared with the collection and testing of blood or tissue samples from animals.

The purpose of this investigation was to examine the potential for soil and plant analysis as indicators of likely mineral deficiencies or excesses of grazing livestock during different seasons.

Materials and Methods

The investigation was conducted at the Livestock Experimental Station Rakh Khaire Wala, district Leiah, in the province of Punjab, Pakistan. The ranch comprises 400 ha and receives annual precipitation of 250-750 mm restricted to July and August. The soils are sandy and vertisols. The ranch has about 7000 animals of which 2000 are breeding sheeps. The vegetation of the ranch consists of a variety of native and improved forages ranging from grasses, legumes, tree leaves and crop wastes available for grazing animals.

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 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 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 ^{o}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 (0.05M HCl + 0.0125M H_2SO_4) following Rhue & Kidder (1983), while forage samples were prepared and digested according to the procedures of Fick *et al.*, (1979). Se^{2+} analyses of soil and forages were achieved by fluorometry (Whetter & Ullrey, 1978), while Fe^{2+}, Cu^{2+}, Zn^{2+} and Mn^{2+} concentrations were determined by atomic absorption spectrophotometry on a Perkin-Elmer AAS-5000 (Anon., 1980). An atomic absorption spectrophotometer with graphite furnace and Zeeman background corrector was used to determine soils and forage Co concentrations.

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

Results and Discussion

Soil

Soil Cu^{2+} was affected significantly by the sampling periods, but the effect of seasons on soil Cu^{2+} was non-significant (Table 1). The differences among the fortnights were non-consistent during both winter and summer seasons (Table 2). However, an increase in Cu^{2+} content at the 2^{nd} and 3^{rd} fortnights during both seasons was found.

In the present study, soil Cu^{2+} did not differ significantly during both seasons, but it was above the critical level (Rhue & Kidder, 1983) for the normal plant growth. The mean soil Cu^{2+} concentrations observed in the present study were similar to the values reported by Tejada *et al*., (1985) and lower than those reported by Tiffany *et al*., (2001). Copper availability to plants seems to be affected by soil pH. Aubert & Pinta (1977) and Sanders & Bloomfield (1980) suggested that available Cu^{2+} decreases with increase in soil pH. At higher pH, Cu^{2+} adhere to soil components and thus it may have led to decrease in Cu^{2+} in soil solution as cupric ions, which is the available form for plants. Soil Cu^{2+} availability is also related to soil organic matter. Kabata-Pendias & Pendias (1992) reported that Cu^{2+} binding capacity of any soil and Cu^{2+} solubility are highly dependent to the amount and kind of organic matter. In this study, the copper levels above critical value indicate the presence of higher organic matter in the soil.

Significant seasonal and non-significant sampling period effects were 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 only at the last fortnight (Table 2). Overall, soil Fe^{2+} was significantly higher in winter than that in summer.

In this study, mean soil Fe^{2+} concentration was different during both seasons. In both seasons Fe^{2+} values were generally high compared to the critical level (Vieks & Lindsay, 1977). Adequate soil Fe^{2+} values were also 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 in some other studies (Tejada *et al.*, 1987; Prabowo *et al.*, 1991).

There was no seasonal effect on soil Zn^{2+} concentration, whereas the effect of sampling period was found to be significant (Table 1). Soil Zn^{2+} was found to be maximum at the 2^{nd} fortnight during winter and at the 3^{rd} fortnight during summer, whereas at the remaining fortnights the soil Zn^{2+} did not differ significantly (Table 2).

In the present study, soil Zn^{2+} contents across all samples during both seasons were almost similar, and these values of soil Zn^{2+} were above the critical level for normal plant growth (Rhue & Kidder, 1983). Similar values above critical levels have already been reported by Prabowo *et al*., (1991) in Indonesia and Tiffany *et al*., (2001) in North Florida. Slightly higher soil Zn^{2+} in winter than in summer as found in this study is in agreement with the findings of Velasquez-Periera *et al.*, (1997). In contrast, Pastrana *et al*., (1991) found higher soil Zn^{2+} concentration in summer than that in winter. Extractable Zn^{2+} has been found to be affected by low pH and cultivation (Aubert & Pinta, 1977). Zn^{2+} may be more soluble and susceptible to leaching in low pH soils and high rainfall areas.

There was a significant effect of seasons but non-significant of fortnights on soil Mn^{2+} level (Table 1). The soil contained higher level of Mn^{2+} during summer than that during winter. A sharp decrease from fortnight 1 to fortnight 2 followed by an increase at both fortnights 3 and 4 was found during winter. In contrast, during summer, an increase up to fortnight 2 was observed followed by a consistent lag phase up to the last fortnight (Table 2).

The minimum dietary Mn^{2+} requirements of ruminants are not precisely known, but likely they range between 15-25 mg/kg for animals (Anon., 1980, 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 Mn^{2+} deficiency have been observed in certain regions including Mato Grosso, Brazil (Mendes, 1977).

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 & 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 & Pendias, 1992). When Mn^{2+} is reduced, its susceptibility to leaching increases. A significant difference was observed in forage Mn^{2+} level in different seasons. Forage Mn^{2+} was above the requirement of livestock during winter and below the required level during summer, although 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).

Soil Co^{2+} concentration was not affected significantly by seasons or sampling periods (Table 1). A high elevation in soil Co^{2+} was observed at fortnight 1 during winter, which thereafter decreased and remained so up to the last fortnight, whereas during summer the soil Co^{2+} concentrations remained statistically unchanged throughout the season (Table 2).

In the present study, mean extractable soil Co^{2+} concentration was 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).

Analysis of variance of the data showed that both seasons and fortnights had a significant effect on soil Se^{2+} concentration (Table 1). Higher Se^{2+} was present in the soil during winter than that during summer. There was a consistent decrease in soil Se^{2+} with time in winter, whereas in summer, a change in soil Se^{2+} was not consistent (Table 2).

The present study showed that soil Se^{2+} content was very low and below the requirement for plant growth during both seasons. Similar levels of soil Se^{2+} had already been reported (Merkel *et al*., 1990). In contrast, higher soil Se^{2+} levels were reported by Rojas *et al*., (1993) and lower by Pastrana *et al*., (1991). McDowell *et al*., (1989) reported seasonal fluctuations in soil Se^{2+} levels, higher in dry season and lower in wet season quite parallel to what was observed in the present study. The mobility of Se^{2+} in soil depends upon soil pH, oxidation potential, organic carbon, calcium carbonate and cation exchange capacity (Banueles & Schrale, 1989).

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

Source of variation	Degree of freedom	Mean squares					
		Cu^{2+}	Fe^{2+}	Zn^{2+}	Mn^{2+}	Co^{2+}	Se^{2+}
Season (S)	1	0.0003ns	877.60**	3.06ns	285.23*	0.000004ns	0.007***
Error	28	0.497	25.24	1.75	37.10	0.0003	0.00004
Fortnight (FN)	3	1.58*	55.90ns	5.59*	10.70ns	0.00005ns	0.0007***
S x FN	3	0.29ns	37.40ns	1.70**	88.69*	0.00008***	0.0003***
Error	84	0.33	46.67	0.49	15.75	0.00004	0.00003

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

Table 2. Micro-mineral concentrations of soil by season and sampling period at sheep ranch.

Element mg/kg	Season	Sampling Periods				
		I	II	III	IV	Seasonal means
Cu^{2+}	**Winter**	3.90+0.152	5.38+0.343	2.17+0.412	3.88+0..35	3.069
	Summer	3.64+0.447	3.68+0.471	2.47+0.23	5.27+0.165	4.094
Fe^{2+}	**Winter**	72.30+2.09	52.80+4.89	58.00+2.40	42.00+5.44	58.45
	Summer	51.60+3.93	50.60+2.18	30.20+2.52	42.00+2.44	48.85
Zn^{2+}	**Winter**	b 6.29+0.202	a 6.18+0..592	b 5.18+0.258	b 6.06+0.340	5.59
	Summer	b 4.18+0.140	b 5.70+0.581	b 6.62+0.186	b 5.98+0.185	4.28
Mn^{2+}	**Winter**	ab 72.80+3.48	C 57.60+2.14	bc 57.80+2.27	bc 59.40+2.09	61.65
	Summer	ab 65.60+2.14	a 69.20+1.86	ab 64.20+1.86	ab 67.00+1.67	65.50
Co^{2+}	**Winter**	A 0.334+0.001	b 0.0280+0.0013	b 0.0256+0.0016	b 0.0282+0.001	0.029
	Summer	b 0.0254+0.0016	b 0.0246+0.002	b 0.0260+0.0016	b 0.0298+0.002	0.028
Se^{2+}	**Winter**	a 0.0894+0.0019	b 0.0788+0.0027	b 0.0786+0.0014	c 0.0698+0.002	0.079
	Summer	de 0.0582+0.0017	d 0.0562+0.0017	de 0.0582+0.0024	e 0.0540+0.0023	0.058

Means with the same letters do not differ significantly at P≤0.05 and Means are based on following number of samples of: soil (60) during each season

Forage

Data for the different forage species were pooled within each season to assess the influence of fortnights and seasons, which was found to be significant on forage Cu^{2+} concentration (Table 3). During winter the lowest forage Cu^{2+} level was found at the last fortnight, whereas at the earlier three fortnights the difference in Cu^{2+} was not significant. In contrast, during summer, a consistent and statistically non-significant decrease in forage Cu^{2+} with time was observed. 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. The forage Cu^{2+} level in forage during winter was within the range of animal's requirement, but was on the borderline requirement during summer (Reuter & Robinson, 1997). Similar low forage Cu^{2+} levels have already been reported in Nigeria (Ogebe & McDowell, 1998; Ogebe *et al.*, 1995) and North Florida (Tiffany *et al*., 2001), in Guatemala (Tejada *et al.*, 1987), Florida (Espinoza *et al*., 1991) and Venezuela (Rojas *et al.*, 1993). Cu^{2+} deficiency can arise when high intakes of Mo and S occur, coupled with normal copper intakes (Underwood, 1981).

Seasonal and fortnights effects were found to be significant on forage Fe^{2+} levels (Table 3). Forage Fe^{2+} concentration was markedly higher in winter than that in summer. A slight reduction in forage Fe^{2+} level was observed with time during both seasons (Table 4).

Forage Fe^{2+} concentration varied significantly by seasonal influence, and it was greater than the requirement of ruminants in winter and deficient in summer. Forage iron 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) did not find Fe^{2+} deficient forage samples in Colombia and Guatemala, respectively. 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 & 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 the same during both seasons and both feed and water Fe^{2+} concentration seemed to complement the forage Fe^{2+} level required by the ruminants.

Both seasons and sampling time had significant effects in changing the forage Zn^{2+} concentration (Table 3). Forage Zn^{2+} level was markedly higher during winter than that during summer. A decreasing trend in forage Zn^{2+} level was observed with time during both seasons (Table 4).

Forage Zn^{2+} concentration showed seasonal variation, with high concentration during the winter season and above the requirement of ruminants, but in summer all samples were deficient or below the critical level (McDowell *et al*., 1993). Similar seasonal differences in forage Zn^{2+} levels were reported by Velasquez-Pereira *et al*., (1997) in Nicaragua. Forage Zn^{2+} varied considerably depending on various ecosystem, characteristics, plant species, and stage of maturity. However, Kabata-Pendias & Pendias (1992) reported that Zn^{2+} concentration of certain forages from different countries do not differ significantly.

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

Source of variation	Degree of freedom	Mean squares					
		Cu^{2+}	Fe^{2+}	Zn^{2+}	Mn^{2+}	Co^{2+}	Se^{2+}
Season (S)	1	3573.74 ***	394490.00 ***	18250.16 ***	38160.32 ***	0.027***	0.027***
Error	28	14.67	49.69	27.16	26.07	0.0003	0.001
Fortnigt (FN)	3	71.11***	424.37***	272.62**	173.99***	0.008***	0.001ns
S x FN	3	19.23**	7.27ns	45.36**	49.13**	0.004**	0.0007ns
Error	84	3.73	6.92	5.78	8.22	0.001	0.0004

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

Table 4. Micro-mineral concentrations of forages by seasons and sampling period at sheep ranch.

Element mg/kg	Season	Sampling Periods				
		I	II	III	IV	Seasonal means
Cu^{2+}	**Winter**	a 29.44+1.35	b 33.72+1.46	b 28.72+1.61	c 17.30+1.39	25.63
	Summer	d 12.00+0.71	e 8.20+0.36	e 6.56+1.60	e 4.48+0.12	7.81
Fe^{2+}	**Winter**	16.60+2.32	195.20+1.85	155.00+1.84	134.20+2.58	161.25
	Summer	35.20+1.16	48.20+1.28	32.00+1.41	16.60+1.66	28.25
Zn^{2+}	**Winter**	a 68.64+1.50	b 65.24+1.63	b 59.16+0.91	c 46.06+2.21	59.53
	Summer	d 18.80+1.66	e 14.80+0.86	e 14.80+0.66	e 12.20+1.28	15.65
Mn^{2+}	**Winter**	a 77.38+1.82	b 71.78+1.65	b 69.90+1.19	c 64.28+2.28	67.59
	Summer	d 14.00+1.36	d 12.80+0.86	d 15.00+0.71	d 10.40+0.75	17.00
Co^{2+}	**Winter**	a 0.1440+0.0136	d 0.1306+0.0174	a 0.1290+0.0116	a 0.1260+0.0093	0.107
	Summer	b 0.0760+0.0051	cd 0.0380+0.0051	bc 0.0570+0.0037	cd 0.0380+0.0020	0.068
Se^{2+}	**Winter**	0.1120+0.0086	0.1000+0.0071	0.1120+0.0086	0.0774+0.0173	0.098
	Summer	0.0500+0.0071	0.0540+0.0093	0.0540+0.0068	0.2460+0.0051	0.051

Means with the same letters do not differ significantly at $P \leq 0.05$ and Means are based on following number of samples: of forage (60) during each season

There are some controversial reports on Zn^{2+} concentration in plants at the adult stage. For example; Underwood (1981) reported that as plants mature, their Zn^{2+} concentration decreases. In contrast, high concentration of Zn^{2+} has been found in old leaves of plants (Kabata-Pendias & Pendias, 1992).

A significant effect of seasons and fortnights was found on forage Mn^{2+} concentration (Table 3). 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 (Table 4).

Several studies indicated a high tolerance of Mn^{2+} in ruminants (Hansard, 1983). Mineral imbalance typified by excess 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 sheeps. 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 is 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.

Mean squares from the analysis of variance of the data for forage Co^{2+} concentration revealed that both seasons and sampling periods had a significant effect on Co^{2+} concentration in forage (Table 3). Higher values of forage Co^{2+} were found in winter than that in summer. During winter, the forage Co^{2+} level remained almost uniform except at the fortnight 2 where a very sharp depression in Co^{2+} concentration was recorded (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 (Anon., 1980). Similar Co^{2+} deficient forages were found in Nicaragua by Velasquez-Pereira *et al*., (1997), in Florida, USA Espinoza *et al*., (1991). 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 & 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 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.

There was a significant influence of seasons on accumulation of Se^{2+} in forage species, while the sampling periods remained ineffective in affecting the forage Se^{2+} level (Table 3). Generally, forage Se^{2+} level was higher in winter than that in summer (Table 4).

Forage Se^{2+} was on borderline requirement of ruminants in summer, but it was higher in winter. Under central Florida conditions, similar values of forage Se^{2+} have earlier been reported by Espinoza *et al*., (1991). In view of Pope *et al*., (1979) increasing the concentration of S in the forage has a detrimental effect on Se^{2+} availability. A similar trend in the forage Se^{2+} levels was reported by Tejada *et al*., (1987) in Guatemala. Gerloff (1992) reported that Se^{2+} concentration in plants is positively correlated with soil pH. Other factors affecting the Se^{2+} uptake are soil P, S and N concentrations. Among crops brassicas and legumes contain higher Se^{2+} than the other crops. It has been suggested that forage crops containing more than 0.1 mg/kg will protect livestock from Se^{2+} deficiency disorders (Gupta & Subhas, 2000). The low forage Se^{2+} found in this study was related to low Se^{2+} contents in the respective soil. According to Ammerman & Millar (1975) the Se^{2+} concentration of herbage generally reflects the status of the soil. The soluble Se^{2+} content in the soil showed a similar tendency to that of forage in this study.

Based on soil and forage analyses it is concluded that copper, selenium, zinc, manganese and cobalt deficiencies may be limiting sheep productions in this semi-arid region of Punjab, Pakistan. Therefore, supplementation studies are needed to determine the need and economic benefit of trace minerals supplementation.

References

Ammerman, C.B. and S.M. Millar. 1975. Selenium in ruminant. A review. *J. Dairy Sci*., 58: 1561-1577.

Anonymous, 1980. Analytical Methods for Atomic Absorption Spectrophotometry. Perkin-Elmer Corp., Norwalk, CT.

Anonymous. 1984. Nutrient requirements of domestic animals. Nutrient Requirements of Beef Cattle (6th rev. ed.). Natl. Acad. Sci., Washington, D.C.

Anonymous. 1990. Feeding Standards for Australian Livestock. Ruminants. CSIRO: East Melbourne.

Anonymous. 1993. Fertilizer statistics data base. Fertilizer Development of Agriculture Nutrient Circular, 939.

Aubert, H. and M. Pinta. 1977. *Trace Elements in Soils*. Elsevier Scientific Publishing Co., NY.

Banuelos, G., and G. Schrale. 1989. Plant that remove selenium from soils. Calif. Agric., May-June, pp. 19-20.

Becker, R.B., J.R. Henderson and R.B. Leighty. 1965. Mineral malnutrition in cattle. *Bulletin*, 699-*Fla. Agric. Exp. Stn., Gainesville*.

Duncan, D.B. 1955. Multiple range and multiple F-test. *Biometrics*, 11:1-42.

Espinoza, J.E., L.R. McDowell, N.S. Wilkinson, J.H. Conrad and F.G. Martin. 1991. Monthly variation of forage and soil minerals in Central Florida. II. Trace Minerals. Commun. *Soil Sci. Plant Anal*., 22: 1137-1149.

Fick, K.R., L.R. McDowell, P.H. Miles, N.S. Wilkinson, J.D. Funk, and J.H. Conrad. 1979. *Methods of mineral analysis for plant and animal tissues* (2nd ed.). Dept. Anim. Sci., Univ. Florida, Gainesville.

Gerloff, B.J. 1992. Effect of selenium supplementation on dairy cattle. *J. Anim. Sci*., 70: 3934.

Gupta, U.C. and C. Subhas. 2000. Selenium in soils and crops, its deficiencies in livestock and Humans: Implications for management. Commun. *Soil Sci. Plant Anal*., 3:1791-1807.

Hannam, R.J., G.J. Judson, D.J. Reuter, L.D. McLaren and J.D. McFarlane. 1980. Effect of vitamin B_{12} injections on the growth of young Merino sheep. *Aust. J. Agric. Res*., 31:347-55.

Hansard, S.L. 1983. Microminerals for ruminant animals. *Nutr. Abstr. Rev. Ser*. B. 53No.1. pp-24-35. Commonwealth Bureau of Nutrition.

Judson, G.J. and J.D. McFarlane. 1998. Mineral disorders in grazing livestock and the usefulness of soil and plant analysis in the assessment of these disorders. *Aust. J. Exp. Agric*., 38:707-723.

Judson, G.J., I.W. Caple, J.P. Langlands and D.W. Peter. 1987. Mineral nutrition of grazing ruminants in southern Australia. In: *Temperate Pasture-their Production, Utilization and Management*. (Eds.): J. L. Wheeler, C. J. Pearson and G.E. Robards. pp. 377-85. Australian Wool Corporation/CSIRO: East Melbourne.

Kabata-Pendias, A. and H. Pendias. 1992. *Trace Elements in Soils and Plants*. CRC Press Inc., Boca Raton, FL.

Kubota, J. 1968. Distribution of cobalt deficiency in grazing animals in relation to soils and forage plants of the United States. *Soil Sci*., 106: 122-130.

Lebdosoekojo, S., C.B. Ammerman, N.S. Raun, J. Gomez and R.C. Little. 1980. Mineral nutrition of beef cattle grazing native pastures on the eastern plains of Colombia. *J. Anim. Sci*., 15: 1249-1260.

Little, D.A. 1982. Utilization of minerals. In: *Nutritional Limits to Animal Production from Pastures*. (Ed.): J.B. Hacker. pp. 259-83. Commonwealth Agricultural Bureaux: Slough, UK.

McDowell, L.R. 1985. In: *Nutrition of Grazing Ruminants in Warm Climates*. Academic Press New York, pp. 443.

McDowell, L.R. 1997. *Minerals for Grazing Ruminants in Tropical Regions*. Extension Bulletin, Anim. Sci. Dept. Centre for Trop. Agric.,Univ. Florida. pp-81.

McDowell, L.R., J.H. Conrad and F.G. Hembry. 1993. *Mineral for Grazing Ruminants in Tropical Regions*. Univ. of Florida, Gainesville.

McDowell, L.R., J.H. Conrad and G.L. Ellis. 1984. Mineral deficiencies and imbalances, and their diagnosis. In: *Symposium on Herbivore Nutrition in Sub-Tropics and Tropics-Problems and Prospects*. (Eds.): F.M.C. Gilchrist and R.I. Mackie. pp. 67-88. Craighall, South Africa.

McDowell, L.R., Y. Salih, J.F. Hentges., R.M. Mason. Jr. and C.J. Wilcox. 1989. Effect of mineral supplementation on tissue mineral concentrations of grazing Brahman Cattle II. *Trace Minerals Inst. J. Anim. Sci*., 4:6-13.

McKenzie, R.M. 1967. The absorption of cobalt by manganese minerals in soils. *Aust. J. Soil Res*., 5: 235-246.

McKenzie, R.M. 1975. The mineralogy and chemistry of soil cobalt. In: *Trace Elements in Soil-Plant-Animal system* (Eds.): D.J.D. Nicholas and A.E. Eagan. pp. 83-93, Academic Press, Inc.: New York, USA.

Mendes, M.O. 1977. *Mineral status of beef cattle in the northern part of Mato Grosso, Brazil, as indicated by age, season and sampling technique*. Ph.D. Dissertation, Univ. of Florida, Gainesville.

Merkel, R.C., L.R. McDowell, H.L. Popenoe and N.S. Wilkinson. 1990. Mineral status comparisons between water buffalo and Charolais cattle in Florida. *Buffalo J*., 6: 33-41.

Mooso, G.D. 1982. *Warm Seasons Grass and Nutritive Uptake with liquid and solid N.P.K. Fertilizers*. M.S. Thesis. Brigham Young Univ., Provo. UT.

Mtimuni, J.P. 1982. *Identification of mineral deficiencies in soil, plant and animal tissues as constraints to cattle production in Malawi*. Ph.D. Dissertation. Univ. of Florida, Gainesville.

Ogebe, P.O. and L.R. McDowell. 1998. Mineral concentrations of forages grazed by small ruminants in the wet season in Benue State, Nigeria. II. Trace minerals and forage crude protein. Commun. *Soil Sci. Plant Anal*., 29: 1211-1220.

Ogebe, P.O., J.A. Ayoade., L.R. McDowell, F.G. Martin, and N.S. Wilkinson. 1995. Mineral concentration of forages and soils in Benue State, Nigeria. II. Trace minerals, soil pH and organic matter. Commun. *Soil Sci. Plant Anal*., 26: 2009-2021.

Pastrana, R., L.R. McDowell, J.H. Conrad and N.S. Wilkinson. 1991. Mineral status of sheep in the Paramo region of Colombia. II. Trace minerals. *Small Rumin. Res*., 5: 23-34.

Pope, A.L., R.J. Moir, M. Somers, E.J. Underwood and C.L. White. 1979. The effect of sulphur on 75SE absorption and retention in sheep. *J. Nutr*., 109: 1448-1454.

Prabowo, A., L.R. McDowell, N.S. Wilkinson, C.J. Wilcox, and J.H. Conrad. 1991. Mineral status of grazing Cattle in South Sulawasi, Indonesia. 2-Microminerals Amer. *J. Anim. Sci*., 4: 121-130.

Reid, R.L. and D.J. Horvath. 1980. Soil chemistry and mineral problems in farm livestock: a review. *Anim. Feed Sci. Tech*., 5: 95-167.

Reuter, D.J. and J.B. Robinson. 1997. *Plant Analysis. An Interpretation Manual*. 2nd ed. CSIRO Publishing: Melbourne.

Rhue, R.D. and G. Kidder. 1983. *Analytical procedures used by the IFAS extension soil laboratory and the interpretation of results*. Soil Sci. Dept., Univ. Florida, Gainesville.

Rojas, L.X., L.R. McDowell, N.S. Wilkinson and F.G. Martin. 1993. Mineral status of soils, forages and beef cattle in South-Eastern Venezuela. II. Microminerals. *Int. J. Anim. Sci*., 8: 183-188.

Sanders, J.R. and C. Bloomfield. 1980. The influence of pH, ionic strength and reactant concentrations of copper complexing by humified organic matter. *J. Soil Sci*., 31: 53.

Smith, F.W., and J.F. Loneragon. 1997. Interpretation of plant analysis: concepts and principles. In "Plant Analysis. An Interpretation Manual". 2nd Edn. (Eds.): D. J. Reuter and J.B. Robinson. pp. 3-33. (CSIRO Publishing: Melbourne.)

Steel, R.G.D. and J.H. Torrie. 1980. *Principles and procedures of statistics. A Biometrical approach*. (2nd Ed.). Mcgraw Hill Book Co. New York.

Suttle, N.F. and D.G. Jones. 1989. Recent developments in trace element metabolism and function: trace elements, disease resistance and immune responsiveness in ruminants. *Journal of Nutrition*, 119: 1055-61.

Tejada, R., L.R. McDowell, F.G. Martin and J.H. Conrad 1985. Mineral element analyses of various tropical forages in Guatemala and their relationship to soil concentrations. *Nutr. Rep. Int*., 32: 313-323.

Tejada, R., L.R. McDowell, F.G. Martin and J.H. Conrad. 1987. Evaluation of cattle trace mineral status in specific regions of Guatemala. *Trop. Agric*., 64: 55-60.

Tiffany, M.E., L.R. McDowell, G.A. O'Connor, H. Nguyen, F.G. Martin, N.S. Wilkinson and N.A. Katzowitz. 2001. Effects of residual and reapplied biosolids on forage and soil concentrations over a grazing season in north Florida. II. Microminerals. Commun. *Soil Sci. Plant Anal*., 32: 2211-2226.

Underwood, E.J. 1981. *The Mineral Nutrition of Livestock*. Commonwealth Agricultural Bureaux, London.

Vargas, D.R., L.R. McDowell, J.H. Conrad, F.G. Martin, C. Buergelt and G.L. Ellis. 1984. The mineral status of cattle in Colombia as related to a wasting disease "secadera". *Trop. Anim. Proc*., 9: 103-113.

Vargas, E. and L.R. McDowell. 1997. Mineral Deficiencies of Cattle in Central America and the Carbean, Emphasizing Cost Rica. Proc. Int. Conf. Liv. Trop.

Velasquez-Pereira, J.B., L.R. McDowell, J.H. Conrad, N.S. Wilkinson, and F.G. Martin. 1997. Mineral status of soils, forages, and cattle in Nicaragua. I. Micro-minerals. *Rev. Fac. Agron*., 14: 73-89.

Viek, P.L.G. and W.L. Lindsay. 1977. Molyboleum contamination in colarado pasturi soil. In: *Molybderum in the environment*, Vol. 2. The geochemistry, cycling and industrial uses of moybdeum. (Eds.): W.R. Chopped and K.K. Peterson. Pp. 619-650, Marcal Dekkar, Inc. New York.

Whetter, P.A. and D.E. Ullrey. 1978. Improved fluorometric method for determining selenium. *J. Assoc. Anal. Chem*., 61:927-930.

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