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PASTURE CONCENTRATION OF MINERALS IN RELATION TO THE NUTRIENT REQUIREMENTS OF FARM LIVESTOCK

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Abstract

Mineral composition (Ca, Na, Cu, and Zn) of different forages and soils in five agricultural local pastures in the Punjab, Pakistan were studied. They were designated as pastures, feeding sites and situated at a distance of 5 km, exhibiting varied vegetation. Grazing animals were followed, and forages corresponding to those consumed by them, and the corresponding soil samples were collected during the winter and summer seasons and analyzed for mineral composition. Most forage samples as well as their corresponding soil samples were not sufficient for most minerals. Some low levels in soil Zn were found in two pastures during summer and winter seasons. Winter season soil Ca and Cu concentrations were significantly higher ($p<0.05$) than summer season; perhaps owing to leaching in all five pastures in summer. Most forage samples had very marginal mineral concentrations, below the critical levels known to be adequate for normal ruminant requirements. Forage levels of Ca, Na, Cu, and Zn were found to be significantly increased ($p<0.05$), generally, with plant maturity from summer to winter. Grazing ruminants in the pastures might possibly be deficient in most minerals and these grazing pastures are not providing adequate levels of the minerals to the livestock grazing therein. Supplementation is the urgent need for grazing livestock to prevent deficiency diseases due to mineral imbalances.

Introduction

Plants are the basic and potential source of food for animals; ultimately the nutritional values of plants are of central importance in determining the plants and human health. Herbs are an important source of delivering minerals to grazing livestock in extensive and low-input situations. At the same time mineral deficiencies can depress forage digestibility and herbage intake and ultimately decrease livestock production efficiency. Mineral concentrations vary significantly among species ranging from toxic to inadequate for livestock production (Grusak & Dellapnna, 1999).

In small holder farming systems, native forages and agricultural by-products are the main mineral sources for ruminant feeds in many regions of the world. The potential of any feed to support animal production depends on the quantity consumed by ruminants and the extent to which the feed meets energy, protein vitamin and mineral requirements (Minson, 1990). The nutritive values of some forage have indicated that these depend on the combined effects of genetic and animal factors. In many dry regions of the world, the feeding of the ruminants mostly depends upon the native grasses and under these conditions ruminants may be exposed sometimes to the danger of deficiency or toxicity of some minerals (Fujihara *et al*., 1992, 1995).

Plant analyses in some instances are necessary for botanical and environmental purposes. The uptake of minerals and particularly trace minerals by plants can provide important information on environmental contamination and requirements of ruminants (Yusuf *et al*., 2003; Khan *et al*., 2006, 2007). Plants absorb minerals from soil as well as from surface deposits on parts of plants exposed to polluted areas. In Pakistan, no information is available so far with reference to the nutritive value, particularly mineral concentrations of different forages in relation to different seasons. Therefore, there is a need to evaluate the mineral concentrations during the summer and winter seasons in relation to ruminant requirements. Information on mineral levels of forages are very important to identify what measures should be taken to improve the nutritional status of grazing livestock. Seasonal variation affects livestock seasonal production in different regions of the world by affecting forage dry matter accumulation (Arizmendi-Maldonado *et al*. 2001; Khan *et al*., 2004, 2005). Seasonal forage nutrient contents stability may be achieved through successful breeding programmes (Mislevy *et al*., 1999). It is important to know the mineral-nutrient concentrations of new varieties, because forage is the primary source of nutrients for livestock consuming pastures (McDowell, 1992) because mineral-nutrients present in the soil are transported to livestock through the forages on which they feed.

The objectives of the survey were to characterize the mineral status of soil and forage systems and to ascertain when, where and to what extent mineral problems might exist as well as to detect any seasonal differences in mineral levels between summer and winter in a semi-arid region of Pakistan. This information will lead to a better understanding of the likely mineral-nutrient needs of grazing ruminants during particular seasons mostly in Pakistan and other Asian countries with analogous climatic and ecological conditions. Due to imbalanced nutrient availability, different physiological disorders and diseases are being observed in the livestock of the region under study.

Materials and Methods

The study was conducted with soil and different forage grasses during two seasons (summer and winter) from five different pastures at the Livestock Experimental Station, Rakh Khiare Wala at 30º 85′ N latitude and 71º 65′ E longitudes, on a sandy loam soil in the Leiah district, Punjab Province, Pakistan. During winter and summer, day and night temperatures, relative humidity and temperature humidity index were recorded (Table 1). All the pastures at this farm fall under natural region based on potential for agriculture production. These pastures experience fairly low to extremely low rainfall and are thus suitable for semi-arid farming based on utilization of the natural pastures for ruminant ranching with a little or no cropping. These pastures are away from one another at a distance of 5 km and referred to as units or feeding sites of this farm.

Collection and preparation of samples for mineral analysis: Five representative soil and forage samples were collected thrice, in the summer and in the winter season. The forage samples both grazed and browsed were collected after careful observation and simulating the grazing behaviour of the ruminants therein, clipped using steel scissors and plastic gloves. Soil samples were taken from below the clipped forages at 0-20 cm depths, using a soil auger, with composite samples obtained by sub sampling combined samples. The soil and forage samples were taken from five positions per grazing pasture area and distance between sampling positions was not less than 40 m (Anon., 1979). The grazing pasture area was stratified according to variations in soil and forage in order to obtain representative sampling positions. Forages samples were dried in an oven at 60º C for 48 h, ground using a hammer mill and passed through a 1 mm sieve. The ground samples were stored in closed plastic bags awaiting chemical analysis. Oven-dried soil was also stored in closed plastic bags. To prepare samples for mineral determinations, 1 g of ground sample of forage was heated in 10 mL HNO_3 and $HClO_4$ (3:1 ratio) at 250^o C until the tissue was completely digested. The digested material was diluted to 50 mL with distilled water and stored at 4^{o}C (Anon., 1990) and were determined using an atomic absorption spectrophotometer (Pye Unicam Ltd. York Street, Cambridge, UK). Soil samples from each pasture after thorough mixing and grinding were passed though a 2 mm sieve and were analyzed for soil minerals (Anon., 1954; Jackson 1962).

The data were analyzed by Analysis of Variance using a split-plot design (Steel & Torrie, 1986). For those variables, which were significant ($p \leq 0.05$), the means were separated using Fisher's Least Significant Difference test (LSD).

Results

Soil: Results for soil mineral concentrations are given in Table 1. Mean soil Calcium levels varied between pastures and the differences were statistically ($p<0.05$) significant. Higher soil calcium levels were recorded in pasture A followed by pasture D and C while the lowest levels were found in pasture B followed by pasture E and D during both winter and summer seasons. Levels of calcium were significantly higher ($p<0.05$) during the winter season in all pastures except for pasture B, where levels during the winter and summer seasons were not significantly ($p>0.05$) different. However, mean calcium levels in all pastures were higher than the critical level of 72 mg/kg of soil dry matter suggested by Rhue & Kidder (1983). Calcium deficiencies in soil samples were at marginal level of requirement for forages only for pasture B, with no recorded deficiencies in other pastures of the farm.

The lowest soil sodium levels were also recorded in pasture B and highest in pasture D during summer season. This pasture has deep sandy soils, which are inherently low in fertility as nutrients are quickly leached beyond the root zone of forage plants. Mean soil sodium levels did not differ significantly ($p>0.05$) between seasons. This is in agreement with results found by Khan *et al.,* (2005, 2006) in other pastures of the same farm where it was shown that sodium levels in soil did not differ significantly between seasons.

The lowest level of soil Cu was observed in pasture A and highest in pasture D during both summer and winter, respectively. All soil samples from the five pastures had more than adequate levels of copper. The mean soil copper concentration was much higher than the critical level of 0.3 mg/kg as stated by McDowell *et al*., (1984) and Rojas *et al.,* (1993). Winter season copper levels in soil were significantly higher ($p<0.05$) than summer season levels, which could be attributed due to incessant rains ($p<0.05$) in this particular semi-arid region. In all pastures, the soil Cu level was lower during summer than winter season.

Table 1. Meteorological conditions (Mean ±SD) recorded during the experimental periods.

Winter				Summer			
	Temperature (^{o}C)	**Relative Humidity (%)**	**THI**		**Temperature (^{o}C)**	**Relative Humidity (%)**	**THI**
Day	11.8±2.9	67.9±19.5	53.7±4.6	Day	47.9±4.8	41.8±12.3	79.4±2.7
Night	6.8±3.9	85.6±13.7	44.6±6.3	Night	21.8±4.6	52.2±12.6	55.5±5.8

THI = Temperature Humidity Index calculated as follows: THI = 04 (dry-bulb thermometer temperature ^{o}F + Wet-bulb thermometer temperature ^{o}F) + 15.

Table 2. Mean mineral concentration of soil minerals during (DM) different seasons in different pastures.

Pastures	**Season**	**Minerals (mg/kg)**			
		Calcium	**Sodium**	**Copper**	**Zinc**
Patsure-A	Summer	290	210	14.45	4.40
	Winter	1420	320	35.64	14.76
Pasture-B	Summer	250	150	23.35	18.84
	Winter	290	180	68.28	3.65
Pasture-C	Summer	940	315	55.26	58.95
	Winter	1140	566	89.15	68.55
Pasture-D	Summer	850	735	76.78	63.86
	Winter	1350	465	95.90	86.25
Pasture-E	Summer	644	270	28.14	42.76
	Winter	876	345	67.24	28.45
Critical values*		<72	<62	<0.3	<1-2.5

*Rhue & Kidder (1983)

Wide variations in concentrations also characterized the soil zinc status. Most of the soil samples collected from pasture B had zinc levels higher than the critical level of 2.5 mg/kg (Velasquez-Pereira *et al*., 1997). Zinc was found to be very low during the winter season from pasture B followed by pasture A during summer. Pasture A, C and D contained higher soil Zn during winter than that during summer, while reverse was true for other pastures. Soil texture was reported to have a significant effect on zinc distribution in Pakistani soils, particularly in semi-arid region, with heavier textured soils having more zinc than the lighter textured sandy soils have already been studied in this semi-arid region of Pakistan by Khan *et al.* (2004, 2005, 2006 and 2007). The effect of season was not profound and variations in soil zinc among the pastures were very minor.

Forage: Most of the forages analyzed contained minerals below the critical levels for ruminant requirements (Table 2). All forage minerals were found to be deficient mostly during the summer season. All pastures except pasture C during winter and D during summer had very low levels of forage Na. The pasture B contained the lowest forage sodium levels, while variations among pastures of other minerals were found ($P>0.05$) to be non-significant. All summer season samples were deficient in calcium and zinc, while sodium was deficient in all samples analyzed for all pastures during both seasons. The mineral concentration ranges were found to be similar to those reported by different earlier researchers (Espinoza *et al*., 1991; Cuesta *et al*., 1993). Forage mineral values for

Ca, Na, Cu and Zn also compared well with those reported by Khan *et al*., (2006, 2007) for Pakistan. The results of this investigation, therefore, confirm that sub-tropical and tropical forages rarely provide all the mineral requirements of grazing ruminants (McDowell *et al*., 1993). Forage calcium, sodium, copper and zinc concentrations increased significantly ($P<0.001$) with the maturity of forage plants from summer to winter, but the opposite is true for some mineral elements (Mpofu, 1996; Ashraf *et al*., 2005; Khan *et al*., 2005). Sodium and Zn concentrations increased and there was a small decrease in copper concentration found in this investigation. According to some reports, the phosphorus but not the calcium concentration of forage plants decline markedly with advancing maturity, whereas concentrations of zinc and copper may also fall but rarely to the same extent as for phosphorus in forages. This is attributed to the mobility of minerals within the plant where phosphorus is considered to be a highly mobile element (Underwood, 1981; Anon., 1984; Dierenfeld *et al*., 1995; Ndebele *et al*., 2005).

Calcium levels in the soil were found to be adequate in this investigation, but they were deficient in forages for most of the pastures (Table 3). The calcium concentration of forage plants varied greatly and the sources of variation in calcium concentration include type of forage, portion of the plant fed by the animals and stage of forage maturity (Dierenfeld *et al*., 1995; Ndebele *et al*., 2005; Khan *et al*., 2006). If it would be assumed that the collected forage samples represents the actual diet of the grazing ruminants in the region investigated, then the calcium concentrations do not meet the requirements of ruminants grazing therein. In addition calcium requirements are also influenced by such animal factors as age, weight and type and level of production. Young animals absorb calcium more efficiently than older animals but they have higher requirement because of a higher rate of growth. (Dierenfeld *et al*., 1995; Ndebele *et al*., 2005). Reuter & Robinson (1997) suggested Ca requirement for maintenance, growing and lactating sheep to be 1200-2600 mg/kg. Thus, the forage Ca values found in this study was considered adequate for the optimum performance of ruminants. Similar forage Ca values as found in this study were reported by Pastrana *et al*., (1991) in Colombia, Tiffany *et al*., (2001) in North Florida, Espinoza *et al*., (1991) in Central Florida and Cuesta *et al*., (1993) in North Florida. The forage mean levels of Ca were found higher than the requirements of grazing ruminants. High levels of Ca of these conserved forages would meet the theoretical Ca requirements of 0.30 % DM Ca diet needed for all forms of production in ruminants (Anon., 1984). These forages had higher levels of Ca than dietary requirement of growing cattle, lactating dairy cows, growing lambs) and lactating ewes. However, efficiency of Ca utilization from these forages, and therefore, its bioavailability in ruminants, would depend on the presence of adequate level of P, active form of vitamin D and calcitonin and parathyroid hormone (PTH). Calcitonin and PTH result in conversion of vitamin D to its active form.

Copper and zinc soil concentrations were found to be high, but forage had inadequate concentrations of these mineral elements (Table 3). This was probably due to the phenomenon of antagonism among other minerals such as molybdenum, sulphur and calcium in the uptake of copper and zinc by forage plants. Evaluation of copper in the forage or other diet for ruminants has limited diagnostic value and can in fact be misleading unless other elements with which copper interacts, particularly molybdenum and sulphur, are determined also for assessing the ruminant requirements in pastures (McDowell *et al*., 1983; Ndebele *et al*., 2005; Khan *et al*., 2005). Forage Cu concentrations were found to be sufficiently low in most pastures to meet the demand of animals during both seasons. Forage Cu values found in this study were much lower except in pasture A and D during winter than the critical limits, but these values were higher than those reported by Tiffany *et* *al*., (2001) in north Florida, and Espinoza *et al*., (1991) in central Florida. However, Cu values reported in the present study were similar to those reported from Indonesia (Prabowo *et al.,* 1990) and lower than those reported by Tejada *et al.,* (1985; 1987) in Guatemala. McDowell *et al*., (1993) reported that Cu interacts strongly with trace minerals and macro-nutrients for absorption by the plants. Calcium in the form of carbonate precipitates Cu, making it unavailable for the plants. In addition, the Cu content is inversely related to increasing plant maturity (McDowell *et al*., 1983).

Zinc concentrations in forage during both the summer seasons were not adequate for the need of grazing ruminants (McDowell *et al*., 1993). Zinc requirements of grazing livestock are not precisely defined, but results of some investigations suggest requirements to be between 20 and 40 mg/kg diet dry matter (McDowell *et al*., 1983; Dierenfeld *et* al., 1995; Ndebele *et al*., 2005). Zinc deficiencies have been reported in ruminants grazing forages low in zinc or high in compounds like cadmium, iron, magnesium, manganese, molybdenum and sulphur, which interfere with Zn utilization in ruminants (Anon., 1984; Ndebele *et al*., 2005). Forage Zn concentration was much lower than the Zn requirements of ruminants particularly during summer than that during winter. However, the level in winter was considered slightly deficient for growing and lactating animals (Prabowo *et al.,* 1991; Tiffany *et al*., 2001). Plant maturity has also been reported to affect Zn concentration of forage and it also depends upon the tissue type of plants (Underwood, 1981; Kabata-Pendias & Pendias, 1992). The Kenya standing committee on Agriculture (Corbett, 1990) indicates that Zn requirement is approximately 25 µg/g of dry matter. The summer and winter values for Zn were found to be much lower except pasture C and D during winter. But according to NRC (Anon., 1984) the required Zn during summer is 70-75 ug/g dry matter and so the values for Zn in summer were within the required levels. Therefore, based on this criterion, the forage Zn values were found to be much lower during both the season in this investigation.

Table 3. Mean mineral concentration of forage minerals during (DM) different seasons in different pastures.

Pastures	Season	Minerals			
		Calcium (%)	Sodium (%)	Copper (mg/kg)	Zinc (mg/kg)
A	Summer	0.214	0.0150	3.42	5.34
	Winter	0.756	0.022	8.84	22.43
B	Summer	0.367	0.0197	4.8	15.66
	Winter	0.690	0.0188	13.24	27.90
C	Summer	0.284	0.0210	2.87	24.66
	Winter	0.718	0.0800	6.35	30.15
D	Summer	0.276	0.0452	4.32	9.42
	Winter	0.944	0.0324	9.55	25.60
E	Summer	0.788	0.0196	3.15	15.50
	Winter	0.382	0.0278	6.45	27.85
Critical values*		0.3	0.08	8	30

*McDowell *et al.,* (1984) and Anon. (1984)

Deficient sodium concentrations in forages in this study could suggest that grazing ruminants in these pastures are prone to Sodium deficiencies and therefore supplementation is needed. This widespread deficiency in forage Na is in agreement with some earlier findings (McDowell *et al*., 1993), that one of the most prevalent mineral deficiency for grazing animals in the world is Na. In addition, deficiency of this element has been reported in many developing countries, e.g., Nigeria (Ogebe *et al*., 1995), Colombia (Pastrana *et al*., 1991) and in Pakistan (Khan *et al*., 2005, 2007).

The content of Na in the ration is important in determining the adequacy of the minerals. To meet the need of highly productive animals, forage should contain more than 0.15 % DM sodium (Anon., 1973). Sodium deficiency is more likely to occur in animal grazing tropical pasture species and these plants generally accumulate less Na than temperate species (Morris *et al*.,1980; Khan *et al*., 2004). Natural forages low in Na have been reported in numerous tropical countries throughout the world (McDowell, 1985).

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