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PERIODIC EVALUATION OF POTASSIUM TRANSFER FROM SOIL AND FORAGE TO SMALL RUMINANTS ON AN EXPERIMENTAL STATION IN SOUTHERN PUNJAB, PAKISTAN

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Abstract

The premier purpose of the present investigation was to appraise the impact of season and the sampling period, the transport of K from soils and forages to sheep grazing in the semi-arid region of Punjab. The ultimate aim was to enhance animal production by employing a balanced K supplementation, if necessary. The samples of soil, H_2O, feed, forage and animal (urine, faeces, milk and blood plasma) were taken eight times fortnightly during two seasons (winter and summer). During summer, K level in soil was found to be adequate for plants, while forage K was above the critical levels for ruminant requirements during both seasons. The plasma K levels were less than required levels in all classes of sheep during both seasons. Milk K concentrations showed no lactation period effect. The lactating sheep had higher faecal K during winter and the non-lactating sheep during summer than that in the male sheep, while urine contained higher K in the lactating as compared to that in the non-lactating sheep during summer and winter. Dietary sources showed no significant effect in enhancing the plasma K status of these animals. Low plasma K may have been due to high excretion through faeces resulting from low absorption and availability through the gastrointestinal tract. Overall, K appraisal based on plasma concentration may be considered inadequate mainly due to unavailability of this mineral from the dietary sources. It is concluded that high bio-available K supplementation is needed for increased animal productivity in this region.

Introduction

Minerals are essential dietary ingredients for ruminants and hence significantly influence the production of grazing livestock. It has been reported that mineral deficiencies are one of the most limiting adversaries to ruminant production world-over (Khan *et al.*, 2008). As the forages are the sole sources of minerals for grazing livestock in Pakistan, so their deficiencies during the dry season affects production during this season. The requirement for K is higher for ruminants than for non-ruminants and for ruminants the requirement is about 0.5-0.8 % (Anon., 1996; 2005). The K requirement appears to be increased for livestock under stress conditions (McDowell, 2003).

Considering all required minerals, K is most affected by forage maturity. Young actively growing forage may contain excess K in the range of 4-5 %, while mature forages are often less than 0.4-0.5 %. Milk potassium is not affected by diet, season or stage of lactation; this is generally true for all macro minerals (McDowell, 2003).

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Several reports have pointed out imbalances of different mineral elements in the province of Punjab (Pakistan) during different seasons (Khan, 2003; Khan *et al.*, 2008). Mineral concentrations of soils and forages have been evaluated during winter and summer seasons, but despite this, adequate information on some elements like K is still lacking. This element is abundant in many soils of Punjab, Pakistan, and during periods of active growth forage plants normally contain amounts exceeding the dietary levels (0.6 to 0.8 %) recommended for ruminants (Anon., 1996). Deficiencies have been reported on low forage and high concentrate diets (McDowell & Valle, 2000; McDowell, 2003).

Khan (2003) had confirmed the K deficiency for ruminants grazing forages exclusively in Pakistan. Clinical signs disappeared promptly after administration of K (Smith *et al*., 1980; McDowell & Valle, 2000). In certain regions of the world, on maturity, a significant deficiency in forage K level occurred (McDowell, 1997; McDowell & Valle, 2000; Khan, 2003). The main reason for lack of widespread K deficiency, even when forages contain lower than the requirement, is likely due to the deficiencies of other nutrients in forages. It is likely that K deficiency will not be expressed as long as there are other nutrients that are even more deficient (McDowell & Valle, 2000).

Keeping in view the importance of this element to animals, we intended to document the success of a general feeding strategy for free grazing sheep rather than measuring the exact daily K intake per animal. By having the information on K requirements of the grazing livestock, it would be convenient for the development of efficient K supplementation regimes for grazing livestock in Pakistan and Asian countries.

Materials and Methods

A study was conducted with soil and different forage grasses during two seasons (summer and winter) at the Livestock Experimental Station, Rakh Khiare Wala at 30.85^{o}N latitude and 71.65^{o}E longitude, in the Layyah district, Punjab Province, Pakistan. The detailed description of the site as well as sampling of soil, forage and animal has already been given elsewhere (Khan *et al*., 2008).

Sample preparation for chemical analysis: Standard protocols were employed for chemical analysis. Hesse (1972) and Rhue & Kidder (1983) method was used for soil determinations. The analysis for forage, feed and faecal samples were carried out following the protocols (Koh & Judson, 1986; Anon., 1990; Neathery *et al*., 1990). By using an atomic absorption spectrophotometer (Model 5000; Perkin-Elmer), K concentrations in all samples were estimated following Anon., (1990) and Nockels *et al*., (1993).

Statistical analysis: The data obtained were subjected to statistical analyses using a split-plot arrangement (Steel & Torrie, 1980). The DMR test was used to work out differences among various means (Duncan, 1955).

Results and Discussion

Soil: No seasonal effect was found on K level in soil as shown in Table 1, but a marked influence of sampling intervals ($p < 0.05$) was observed on soil K. Overall, the potassium level was lower in summer that in winter. Sampling time decreased the K concentrations in both winter and summer seasons (Fig. 1a).

Table 1. Analysis of variance (ANOVA) of data for potassium (K^+) at sheep ranch.

Source of variation	df	Mean squares		df	Mean squares	
		Soil	Forage plants		Water	Feed
Season (S)	1	3990.53^{ns}	324065333.3^{***}	1	8.6^{ns}	93896.1^{ns}
Error	28	1498.30	18659976.2	8	4.1	66322.2
Fortnight (FN)	3	1189.43^{***}	40833888.9^{ns}	3	0.40^{ns}	10675.6^{ns}
S × FN	3	74.82^{ns}	199268666.70^{***}	3	0.48^{ns}	40265.5^{ns}
Error	84	56.86	32899849.2	24	0.49^{ns}	38220.2

*** = Significant at 0.001 level; ns = Non-significant.

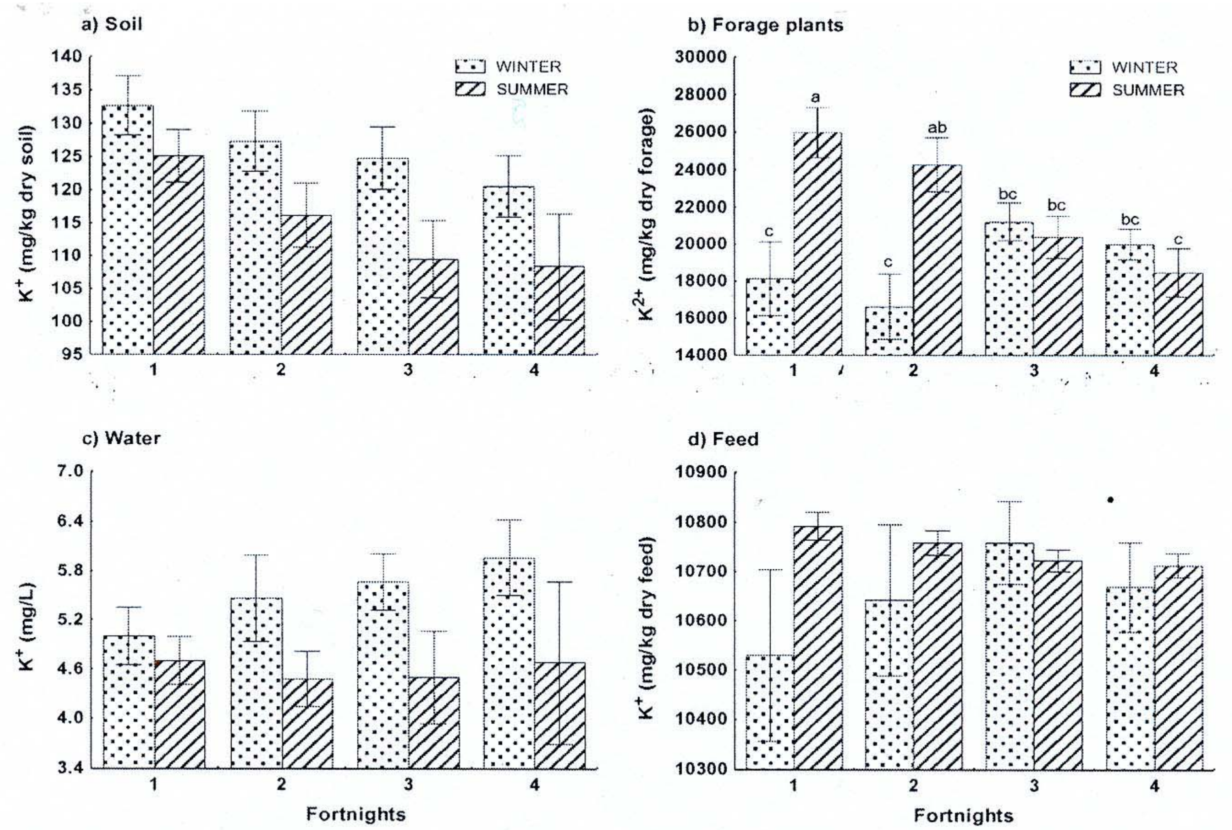

Fig. 1. K^+ concentration in (a) soil, (b) forage plants, (c) water, and (d) feed sampled at different fortnights during winter and summer at the sheep farm.

Forage plants: Forage K level (Table 1) varied significantly ($p<0.001$) in winter and summer, but the effect of fortnights was non-significant ($p>0.05$). In winter, a gradual increase in forage K was found with time, but in summer, the forage K did not vary much at different fortnights (Fig. 1b). Overall, forage K was higher during summer than that during winter.

Water: No significant seasonal or sampling intervals effect ($p<0.05$) was observed on K level in water offered to sheep at the farm (Table 1). A gradual enhancement in K level was observed during winter with sampling time. Conversely, a consistent increase in water K level was observed during summer. Generally, water K was markedly higher in winter than that in summer (Fig. 1c).

Feed: Seasonal/fortnight effect was non-significant on feed K concentration (Table 1). However, in summer feed K concentration decreased with time, while in winter, no consistent pattern of increase or decrease in K concentration was found with time (Fig. 1d). During summer relatively higher feed K level was found.

Animal samples (Lactating sheep)

Plasma: Seasonal ($p<0.05$) as well as fortnight effects ($p<0.001$) on blood plasma K concentration were significant as is evident from the analysis of variance of the data (Table 2a). In winter, the K levels were higher than those in summer (Fig. 2a). K level in plasma during winter decreased from 2nd to 4th fortnight, but at 1st fortnight, K concentration was almost equal to that at fortnight 2. Conversely, in the summer season a substantial decrease in plasma K level was observed with time.

Faeces: K level in faeces showed that both seasons and intervals of sampling (fortnights) did not affect ($p<0.05$) faecal K concentration (Table 2a). The lowest faecal K content was recorded at fortnight 3 during winter. Overall, K concentration was slightly increased during winter than that during summer (Fig. 2b).

Urine: Urine K concentration in both seasons and at different fortnights did not vary significantly ($p<0.05$) as presented in Table 2a. In summer, a marked increase in urine K content was observed, whereas, in winter K content remained unchanged during the first three fortnights, but at the last fortnight a sharp decrease was observed in urine K level (Fig. 2c). In summer urine K level was the maximum.

Milk: A significant effect of fortnights on milk K level was observed, but seasons did not show any significant ($p<0.05$) effect (Table 2a). A substantial increase in K concentration in winter and summer was observed with time (Fig. 2d). The amount of K in urine was higher in winter than that in summer.

Animal samples (Non-Lactating sheep)

Plasma: K level in plasma varied significantly ($p<0.01$) in different seasons, but it showed non-significant changes ($p<0.05$) at different fortnights (Table 2b). In summer, K level was uniform at 1st and 2nd fortnights and thereafter it increased with time but in winter, the maximum plasma K was observed at the 2nd fortnight, while did not vary during the remaining fortnights. During summer plasma contained higher K than that during winter (Fig. 2e).

Faeces: The seasonal effects were non-significant ($p<0.05$) but sampling time had significant effects ($p<0.05$) on fecal K level (Table 2b). In both seasons, there was an increasing tendency in fecal K (Fig. 2f). K concentration in faeces during winter was higher than that in summer (Table 2).

Urine: K concentration in urine was not affected by the seasons ($p>0.05$) of the year, but significantly affected at consecutive fortnights ($p<0.001$) within each season (Table 2b). A linear reduction in K level was observed in both seasons with time .Overall, a slight increase in K level was observed in winter than that in summer (Fig. 2g).

K concentration in urine was not affected by the seasons ($p<0.05$) of the year, but significantly affected at consecutive fortnights ($p<0.001$) within each season (Table 2b). During both seasons, a consistent reduction in K content was recorded with time .Overall, a slight increase in K level was observed in winter than that in summer (Fig. 2g).

Table 2a. ANOVA for potassium concentration of lactating sheep.

Source of variation	df	Mean squares			
		Plasma	Faeces	Urine	Milk
Season (S)	1	7387.01*	1138360.6^{ns}	11139.2^{ns}	148781.3^{ns}
Error	18	1003.8	1341414.3	863495.2	103682.9
Fortnight (FN)	3	1309.2***	317429.1^{ns}	27147.7^{ns}	128831.3***
S × FN	3	142.6^{ns}	885257.2^{ns}	126640.4**	1441.3^{ns}
Error	54	158.7	640832.1	24566.5	12721.4

Table 2b. ANOVA for potassium concentration of non-lactating sheep and that of plasma and faeces of male sheep.

Source of variation	df	Mean squares				
		Non-lactating sheep			Male sheep	
		Plasma	Faeces	Urine	Plasma	Faeces
Season (S)	1	11968.5**	52558.2^{ns}	51842.00^{ns}	318.04^{ns}	327296.1^{ns}
Error	18	870.6	351388.9	814344.4	975.2	406981.9
Fortnight (FN)	3	402.9^{ns}	39660.3*	31475.3***	458.6^{ns}	18195.1***
S × FN	3	867.1**	8608.3^{ns}	163.8^{ns}	924.7**	1085.7^{ns}
Error	54	173.5	10650.00	492.2	214.00	1167.6

ns = Non-significant; *, * *, * * * = Significant at 0.05, 0.01, and 0.001 levels, respectively

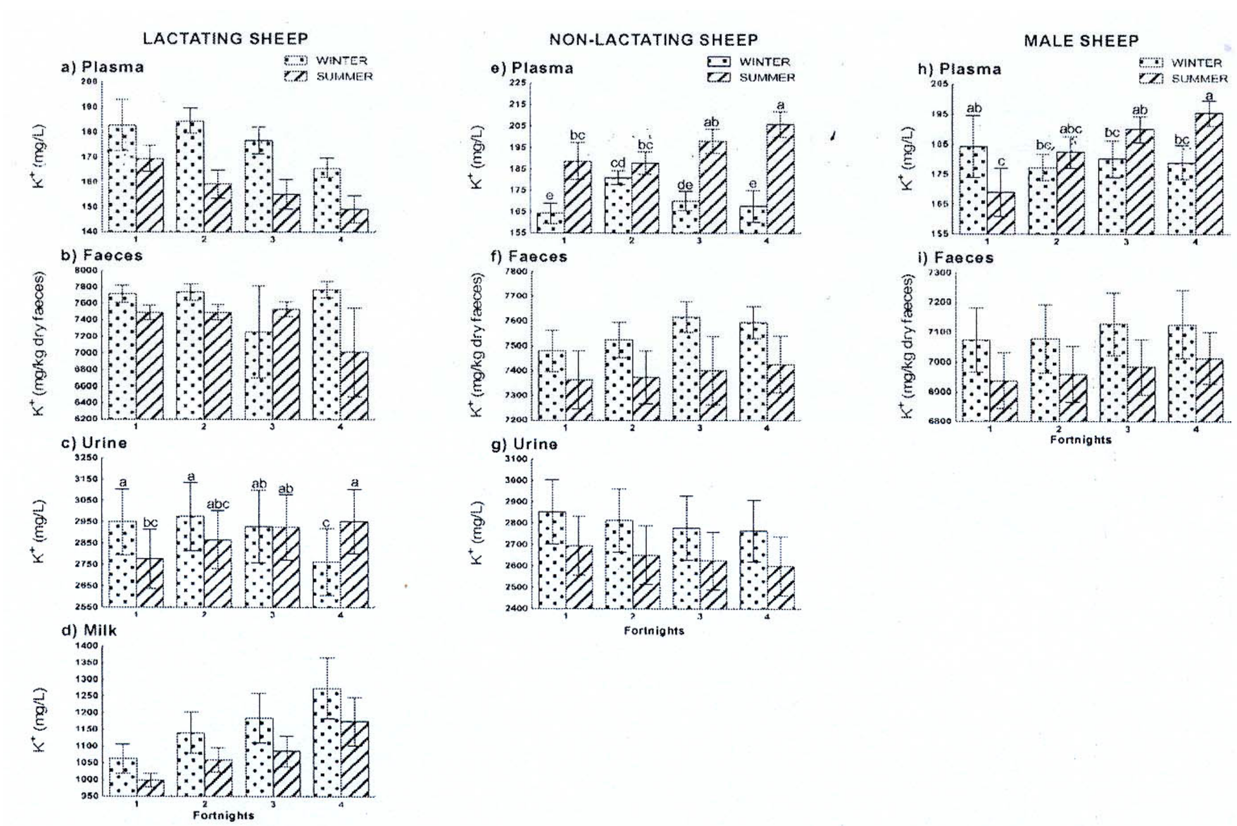

Fig. 2. Concentrations of K^+ in lactating, non-lactating, and male sheep at different fortnights during winter and summer (Means following same letters are not different statistically at p<0.05).

Animal samples (Male sheep)

Plasma: The effects of seasons and fortnights on K level in blood plasma ($p<0.05$) of male sheep were non-significant (Table 2b). A consistent increase was recorded in K level during summer, while in winter, there were inconsistent changes in K with time of sampling (Fig. 2h).

Faeces: Seasons did not affect the faecal K level, but fortnights had a significant effect ($p<0.001$) as shown in Table 2b. The faecal K level was generally lower in summer than that in winter. A slight increase in faecal K concentration was observed with time during both seasons (Fig. 2i).

Discussion

A semi-arid climatic condition like that of the present study certainly influences the mineral composition of soils and forages as well as the animal's metabolism. Therefore, the results presented here can be used with some caution, particularly with reference to hot semi-arid conditions.

Soil K concentrations recorded in both seasons were adequate (Rhue & Kidder, 1983) for the normal growth of plants. This increase in soil K levels was incontrast to Cuesta *et al*., (1993) during the main growing season of their experiment. while, these levels were lower than those recorded by Prabowo *et al*., (1990), Tejada *et al*., (1987) in Guatemala, and Ogebe *et al*., (1995) in Nigeria. Marginal or low levels of soil K have been reported in North Florida (Tiffany *et al*., 2001). Generally, forage K was highly influenced by plant age than soil K. It is evident that young plants have higher K than that in mature plants (Tiffany *et al*., 2000).

Forage K concentrations during winter and summer were within the range for the normal requirements of animals. It tended to be higher in summer than that in winter. Similar K concentrations were also studied by Prabowo *et al*., (1990), Ogebe *et al*., (1995) in Nigeria and Tiffany *et al*. (2000 and 2001) in North Florida. K in growing forage is found to be generally high (McDowell & Valle, 2000). Thus, the livestock received optimum amount of potassium from forages through grazing. The potassium deficiency may arise in certain regions of the world as forage maturity increased (McDowell & Valle, 2000; Ahmad *et al*., 2008). High forage diets typically contain several times the amount of K present in high grain diets. Since K is not readily stored in animals, it must be supplied daily in the diet. Feed and water K levels were adequate to contribute to the requirement of ruminants during both seasons. Plasma K contents of male animals were higher than those in the other classes of animals during winter and that of non-lactating sheep in summer. The plasma K levels in all classes were below the critical level and thus considered deficient during both seasons in spite of high contents of K in the dietary intake. No effect of seasons or lactation periods on milk K content was found, but in early lactation it was slightly higher than that in late lactation.

Faecal K excretion was higher in the lactating sheep during winter than in the other groups of animals, but in summer it was higher in the non-lactating sheep than that of male and lactating animals. However, urine K was higher in the lactating sheep than that in the non-lactating during both seasons. Low plasma K level in summer and winter was not due to the K status in the diet during both seasons, because the forage and feed during both seasons were higher in K content than the requirement (Reuter & Robinson, 1997), and the K content in the source remained ineffective in raising the plasma K up to normal levels in both seasons in all classes of sheep. The dietary K had a pronounced effect in raising the plasma K during winter as compared to that in summer only in the lactating sheep, in contrast to plasma K in the male and non- lactating sheep.

The absorption rate of K through alimentary canal can to be affected by the physiological status of the animals. Higher absorption of K in the lactating sheep and low absorption in the non-lactating and male sheep was found during winter than that during summer. The more K was found to be excreted through faeces in all classes of sheep during this investigation. In this study, a close relationship was found between K absorption and milk K content in the lactating sheep during both seasons. When plasma K was high, the milk K had also been high in these particular seasons. On the other hand, inverse relationships were found between plasma K and faecal K contents in the non-lactating and male sheep, *i.e.*, when plasma K was low, the faecal K was high showing the extent of absorption and non-absorption during both seasons. The gender and age of animals have also been reported to affect the K absorption (Standing Committee on Agriculture, 1990). The animal age may affect mineral requirements through changes in absorption efficiency. Generally, the young ones absorb most of the minerals more efficiently than the older ones. Similar phenomenon may possibly be involved in different classes of animals in this study with respect to rate of absorption.

On the basis of these results, it is concluded that potassium in forage and soil was adequate in relation to plant and animal requirements. However, all classes of sheep were deficient in plasma K during both seasons. Marginal deficient level of K in plasma of the lactating sheep during winter and moderate during summer was found, while in the non-lactating and male sheep K in the plasma was at marginal deficient levels during both seasons. Thus, supplementation of a fortified mineral mixture is required.

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