

SODIUM, POTASSIUM AND MAGNESIUM DYNAMICS IN SOIL-PLANT- ANIMAL CONTINUUM

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Abstract

This study was carried out to evaluate the macro mineral status in dry-non pregnant cows at Rural Domestic Farm. Soil, forage, and blood samples were obtained four times and after wet digestion were analyzed for macro minerals. Effect of sampling periods on soil sodium and Mg, forage K⁺ and Mg⁺², and plasma Na⁺ and K⁺ was found to be significant while the reverse was true for other minerals in different parameters. Soil Na⁺ and Mg⁺², forage Mg⁺² and plasma Mg⁺² was lower than the requirements of grazing livestock while the soil K⁺ forage Na⁺ and K⁺ and plasma Na⁺ and K⁺ were higher than the critical levels recommended for livestock. Based on these results it can be concluded that need of the soil amendment with fertilizers and supplementation of grazing animals with the mixture mineral deficient in forage and blood plasma is not warranted but occasionally supplementation would alleviate the potential hazards of deficiency of these elements in farm animals.

Introduction

Soil-plant factors affects mineral composition of forage plants which includes pH, drainage, fertilization, forage species, forage maturity and interaction among minerals (Gomide, 1978; Reid and Horvath, 1980). In a pasture mineral level varies from species to species, and mineral imbalances occur in different areas of the world. Macro minerals are required in large amounts whereas micro minerals in smaller amounts (Little, 1982). Mineral level of grazing livestock is influenced by the mineral status of soils and forage. The mineral interactions also play an important role in plants and animals (Towers and Clark, 1983). Soil nature and its other physico-chemical properties affect the grazing livestock as it cause mineral deficiency in them, and the forages are the basic source of minerals and nutrition (McDowell, 1997; McDowell, 1985). In dry areas, ruminants mainly graze on native grasses, crop residues and by-products of agro industry and in these grazing conditions ruminants suffer from mineral deficiency, as these food sources has less amount of minerals in them and contained imbalanced mineral level (Vijchulata *et al.*, 1983; Hayashi *et al.*, 1985; Fujihara *et al.*, 1992).

Mineral supplementation is being done for the long term production, grazing cows need mineral supplementation for optimal reproduction, immunity, lactation and growth. The most important minerals for the ruminants are the macro minerals such as calcium, sodium, potassium, chloride, magnesium and sulphur (Underwood, 1981; Masters *et al.*, 1993). It has been reported that concentration of K⁺ is different between the calves and dry cows and varied from animal to animal (Asif *et al.*, 1996). Forages only are not able

to provide all the required minerals for cattle. In addition to forages animals require supplements containing minerals in various proportion. The hypomagnesaemia disorders are caused by the high level of K in the diet, by the taking of immature forages due to low level of magnesium absorption in gastrointestinal tract of grazing ruminants (Ram *et al.*, 1998; Schonewille *et al.*, 1999). However, organisms need minerals to a critical for their metabolic activities (McDowell, 2003). Plants forage concentration can be determined by the analyzing of their uptake by ruminants (Yusuf *et al.*, 2003).

Mineral concentration in plants differs from specie to specie and varies from one place to place in the soil of pasture (Tolsma *et al.*, 1987; Ben-Shahar and Coe, 1992), and they are subjected by seasonal variation (Khan *et al.*, 2006). Sodium deficiency in ruminants is documented in the semi-arid region of Punjab, Pakistan and can be over come by regular supplementation through out the year (Khan *et al.*, 2005 and 2006). It has been reported that with the passage of time mineral status in legumes and grasses decreased as the plants mature (Gonzalez *et al.*, 2006). In addition to soil and forages, blood plasma is the best source for estimation of mineral status in the animals (McDowell, 1985 and Khan *et al.*, 2006). Many parameters are under investigation at the time of selecting a supplement like environmental conditions, management practices, forage types, animal genetics and physiological state of production. The mineral level of ruminants has changed by changing place and season (Khan *et al.*, 2008). To fulfil the requirements of production mineral supplementation is done as it has all the salt solutions which animal need (Khan *et al.*, 2008).

The purpose of this research is to locate the mineral imbalances in grazing animals. This analysis was based on soil, forage, and animal blood plasma. The final goal is to meet the needs of livestock in order to maximizing the animal productions, by adopting, if necessary mineral supplementation for grazing ruminants at this farm of livestock.

Materials and Methods

Investigated site: A Rural Animal Farm of Livestock, was selected for the present study. It is located in the centre of Punjab, district Sargodha, Pakistan. It is situated at latitude 32.8°N and 73.7°E longitude. Its temperature ranges from 7° C to 51° C during winter and summer, respectively. Soil, forage, and blood plasma samples were collected from this experimental station four times with one month interval to assess the transfer of minerals from soil to forage, and forage to blood plasma of cows. All soil and forage samples were collected from squire No. 62 and 63 of pastures at the livestock experimental station concerned.

Soil sampling: Soil samples were collected from the fields where forages were grown, on which the targeted cattle graze round the year. Five sites were selected randomly and soil was collected from the depth of 12-15 cm with the help of stainless steel auger as described by Sanchez (1976). Thus five samples, one from each site, were collected in such a way that all the soil layers were present in equal amounts. The sampling was done four times with the one month interval up to four months. These collected samples were air dried, and then oven dried at 70° C and stored until analysis.

Forage sampling: Cows were managed in the traditional semi-nomadic system. Flocks are accompanied at all times by herdsmen. Cows grazed on the native and improved pasture whole the year. The nature of its soil is predominantly loamy to clay. Forage samples were collected from randomly selected five different feeding places in the

pasture. The forage samples were collected from the same place from where soil samples were collected mostly consumed by the animals. The sampling was done four times with the one month interval and five samples were collected of forages each time of sampling and mixed for evaluating sodium and potassium, and magnesium contents.

Blood sampling: Investigated animals were healthy cows with age ranged from 5-6 years and in physiological state of dry non-pregnant. Blood samples were collected from the jugular vein of these animals with the help of sterilized needle in a heparinised test tube. Four times sampling was done after one month interval and five samples of blood were collected from each time of sampling from these animals. After blood collection plasma was separated by centrifugation at 3000 rpm for 30 minutes following Koh and Babidges (1986). The plasma was stored in small labelled vials and placed the in freezer at -20°C .

Wet digestion and mineral analysis: Soil, forage plants, and blood plasma samples were digested with sulphuric acid (H_2SO_4) and hydrogen peroxide H_2O_2 (1:2). After cooling, the digested samples were diluted with double distilled water to final volume of 50 mL. Na^+ , K^+ and Mg^{+2} of soil, forage plants, and blood plasma samples were analyzed with an atomic absorption spectrophotometer as described by Anonymous (1980).

Statistical analysis: Data thus obtained was statistically analyzed following Steel and Torrie (1980) and statistical significance was tested at 0.05, 0.01 and 0.001 level of probability using the software SPSS.

Results and Discussion

Soil sodium: Analysis of variance for soil sodium, it is evidenced that soil sodium concentration varied significantly ($P < 0.001$) during different sampling intervals (Table 1), the high level of soil sodium was found at sampling period 4th. and lowest at period 2nd. Its values ranged from 32.18 to 16.65 mg/kg. The soil sodium concentration was decreased from period 1st. to 3rd. but it increased suddenly from 3 to 4 sampling interval (Fig. 1). Similar values for Na^+ concentration were investigated from different researchers in the world (Prabowo *et al.*, 1990; Espinoza *et al.*, 1991; Khan *et al.*; 2008). The soil Na^+ level in the study shows the, composition of the underlying layers which all rich in Na^+ (Pastrana *et al.*, 1991). Lower values of soil Na^+ were found at all sampling than the optimal limit 62 mg/kg reported by Rhue and Kidder (1983). To increase the fertility of soil of the studied pasture of livestock farm, Na^+ containing fertilizers should be used in this area for soil amendment. The higher soil Na was reported earlier by Khan *et al.*, (2005 and 2006) while working in another similar animal ranch in Southwestern Punjab, Pakistan.

Table 1. Analysis of variance for Na⁺, K⁺ and Mg⁺² concentrations in soil, forage, and blood plasma at different sampling intervals

SOV	df	Mean squares								
		Soil			Forage			Blood plasma		
		Na ⁺	K ⁺	Mg ⁺²	Na ⁺	K ⁺	Mg ⁺²	Na ⁺	K ⁺	Mg ⁺²
Sampling period	3	245.73 ^{***}	18.72 ^{ns}	246.30 ^{***}	0.038 ^{ns}	0.225 [*]	0.000 ^{**}	2905.71 ^{**}	7.232 [*]	0.433 ^{ns}
Error	16	12.387	19.977	14.501	0.059	0.086	0.000	311.319	2.465	0.311

SOV = source of variation; df = degree of freedom; ***=significant at 0.001 levels; **= significant at 0.01 levels; * = significant at 0.05 levels; ns= non significant

Soil potassium: Analysis of variance for potassium level in soil showed that sampling periods had non significant effect ($p>0.05$) on soil K⁺ concentration (Table 1). A sudden increase was observed from sampling period 1st to 2nd., but it remained uniform up to period 3rd. than it increased during the sampling period 4th. (Fig. 4). Soil potassium concentration varied from 16.70 to 20.74 mg /kg at different sampling intervals during this study. The values of soil K⁺ were found lower than the earlier values determined by Espinoza *et al.*, (1991) in Central Florida and Khan *et al.*, (2007) in Pakistan while working on similar ranch in the Punjab. The possible reason of low soil K⁺ may be because of high K⁺ leaching in soil (Espinoza *et al.*, 1991).

Soil magnesium: Soil Mg⁺² concentration was effected ($p<0.05$) by sampling periods (Table 1). The level of Mg⁺² in soil increased gradually from 1st. to 4th sampling periods. The highest level of Mg⁺² in soils was observed at sampling period 4th and lowest concentration was observed at 2nd sampling period. All mean Mg⁺² concentrations ranged from 21.1 to 37.7 mg/kg with abrupt trend of increase (Fig. 7). Soil Mg concentrations were lower than those observed by Cuesta *et al.*, (1993) and Tiffany *et al.*, (2000). Soil Mg⁺² level observed during our research are lower than critical level of 30 mg/kg established by Rhue and Kidder (1983). This soil requires amendment with fertilizers containing Mg to over come its deficiency in soil.

Forage sodium: Analysis of variance showed non-significant influence ($p>0.001$) of sampling periods on soil Na⁺ concentration (Table 1). Higher concentration of forage Na⁺ was found at period 3rd. as compared to other periods, and lower value of forage Na⁺ found at 1st.sampling period (Fig. 2).

It showed inconsistent pattern of increase or decrease. The forage Na⁺ concentration varied from 1.33 to 1.53 % during different sampling periods. Forage Na⁺ increased up to period 3rd and then suddenly decreased at period 4th. All the mean Na⁺ concentrations were higher than its optimal range 0.06% determined by NRC (1984). Our research investigated that there is no need of supplementations to ruminants at this farm. Our findings were corroborated with the findings of earlier researchers who found similar values of forage Na⁺ (Rahman *et al.*, 1998; Tiffany *et al.*, 2001; Khan *et al.*, 2009) in different regions of the world.

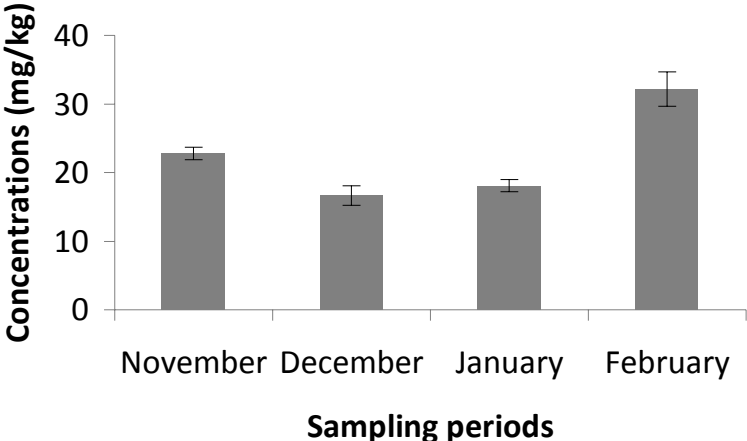


Fig. 1. Fluctuation in soil Na⁺ concentrations at different sampling periods.

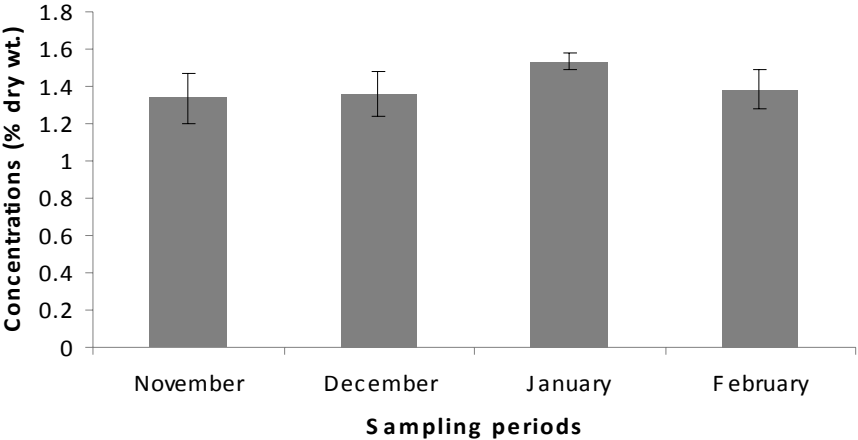


Fig. 2. Fluctuation in forage Na⁺ concentrations at different sampling periods.

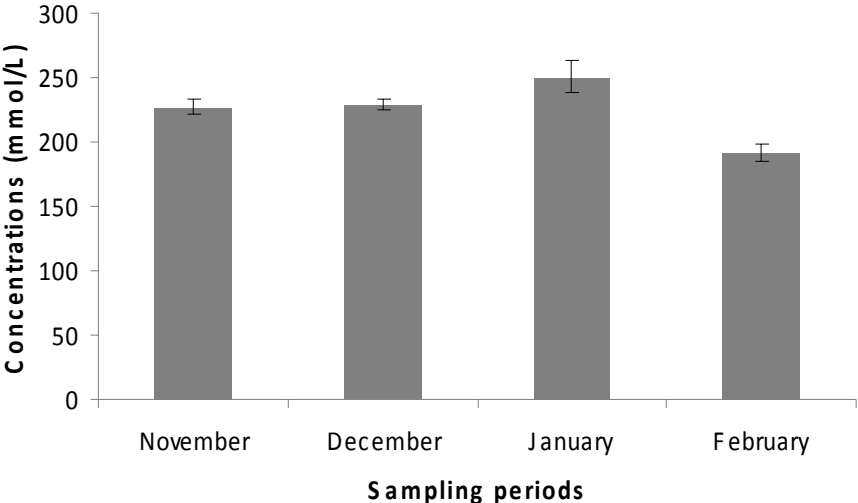


Fig. 3. Fluctuation in plasma Na⁺ concentrations at different sampling periods.

Forage potassium: Analysis of variance for forage potassium showed significant effect of sampling periods on its concentrations ($p < 0.05$) among different sampling periods (Table 1). However, it had inconsistent pattern of increase or decrease in forage K^+ at different sampling periods (Fig. 5). An abrupt increase was observed from sampling interval 1st to 2nd but it decreased at sampling period 3rd, then a slightly increase observed during 4th sampling interval. Higher value forage K^+ concentrations were observed at sampling period 2nd and lower values are found at the sampling period 3rd. Whole K^+ levels were similar at 1st and 4th sampling intervals. Mean K^+ concentration differed from 1.60 to 2.11% during different sampling periods. However, all mean forage concentrations were higher than the optimal values 0.60 % as suggested by McDowell (1977). Present findings of forage K^+ concentrations were similar with the values observed by Espinoza *et al.*, (1991) in Florida, but the forage K^+ concentrations were lower than those determined by Khan *et al.* (2009) in Pakistan.

Forage magnesium: Forage Mg concentration affected significantly ($p < 0.05$) by sampling periods (Table 1). Statistically it is highly significant. The mean forage Mg level differed from 0.115 to 0.136 mg/kg among sampling periods and showed lower concentration at sampling period 4th and higher concentration at sampling period 3rd. The level of Mg in forage varied inconsistently in decrease and increase during different sampling intervals (Fig. 8). Forage Mg concentrations observed in our present study were mostly similar to those concentrations observed by Prabowo *et al.*, (1990) and lower than those reported by Fujihara *et al.*, (1992) and Khan *et al.*, (2009).

Plasma sodium: Sampling periods had significant effect on Na^+ level in plasma ($p < 0.05$) at different (Table 1). Higher plasma Na^+ level was found at sampling period 3rd. and lower value of plasma Na^+ were observed at sampling interval 4th. A gradual increase was found in the plasma Na^+ level up to period 3rd. but suddenly dropped at sampling period 4th having the trend of inconsistent decrease and increase at different times of sampling (Fig. 3). It ranged from 192.17 to 227.39 mmol/L. All mean plasma Na^+ values during present study were higher than the established values (Miles *et al.*, (2001). This high plasma Na^+ level reflected that the present level of Na^+ in forage was considered to be effective during lactation due to secretion of large quality of Na^+ in milk and in sweat. The same results was determined by Khan *et al.*, (2009) for similar area of pasture in south western Punjab, Pakistan, but these values differed from the findings of Rahman *et al.*, (1998) who observed high plasma Na^+ in animals at different ranch of ruminants than those found in our investigation.

Plasma potassium: Analysis of variance showed significant influence of sampling periods on plasma K concentration during this investigation (Table 1). A gradual increase in plasma K^+ level was observed from sampling period 1st. to 2nd. with a sudden increase up to period 3rd. and at this sampling interval higher plasma K^+ value was observed. It showed inconsistent trend of fluctuation at all sampling intervals. Lowest values were observed at sampling period 4th. in our investigation (Fig. 6). Plasma K^+ content ranged from 7.94 to 10.76 mg/L during present study. All the mean K^+ content were higher than the critical value of 2.20 mg/L reported by Grace (1983). Higher Plasma K^+ concentration was observed during our study than those found already by Grunwaldt *et al.*, (2005) in beef cattle in Argentina and Khan *et al.*, (2009) in different ruminants in Pakistan. Similar concentration of plasma K^+ has been observed by Gizachew *et al.*, (2002) in Western Ethiopia. These differences in plasma K^+ may be attributed to the physiological state of animal and different climatic conditions.

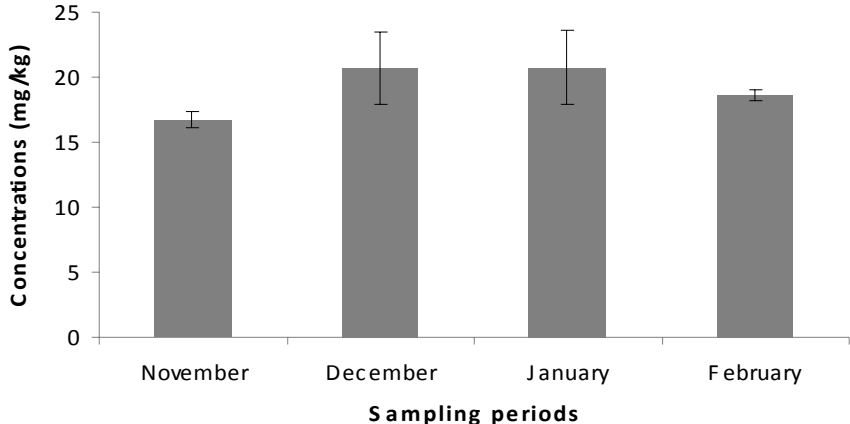


Fig. 4. Fluctuation in soil K⁺ concentrations at different sampling periods.

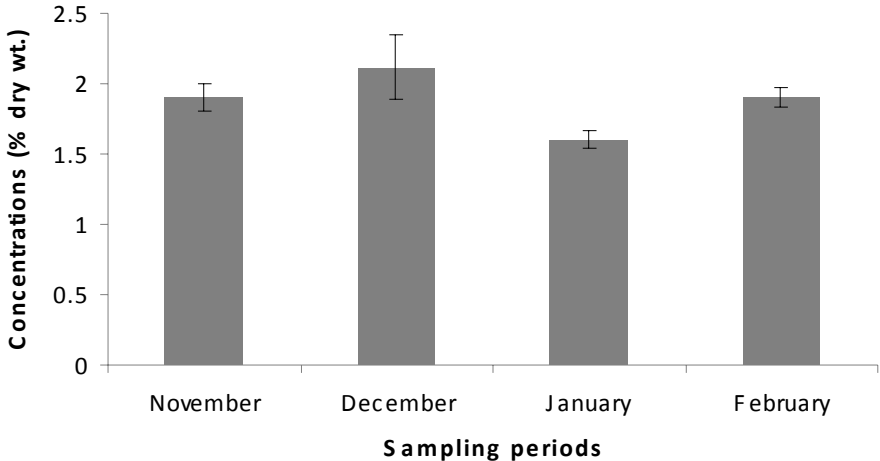


Fig. 5. Fluctuation in forage K⁺ concentrations at different sampling periods.

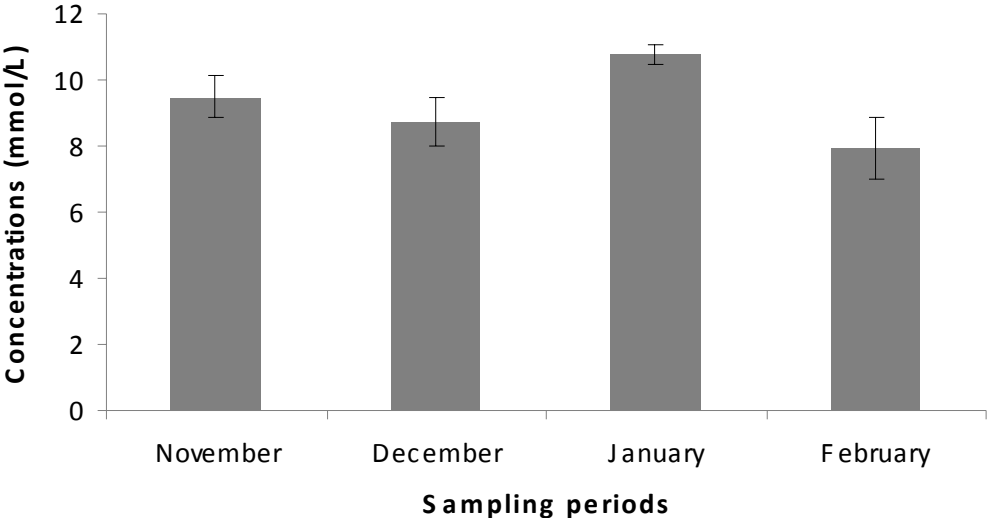


Fig. 6. Fluctuation in plasma K⁺ concentrations at different sampling periods.

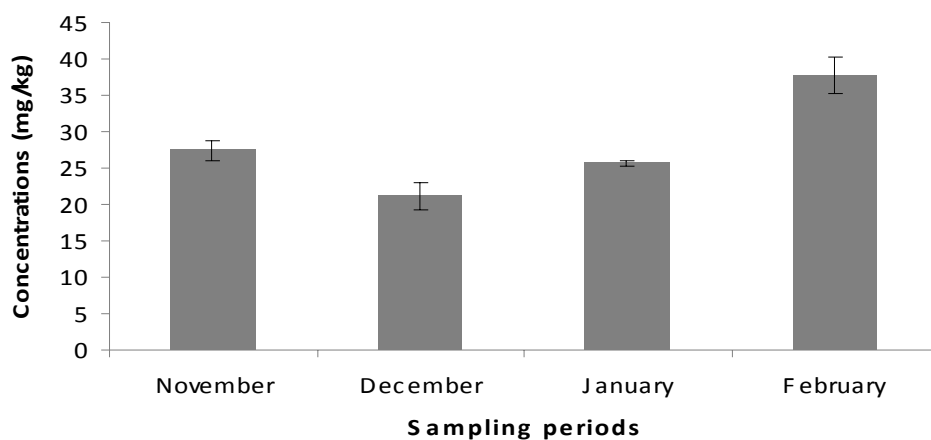


Fig. 7. Fluctuation in soil Mg²⁺ concentrations at different sampling periods.

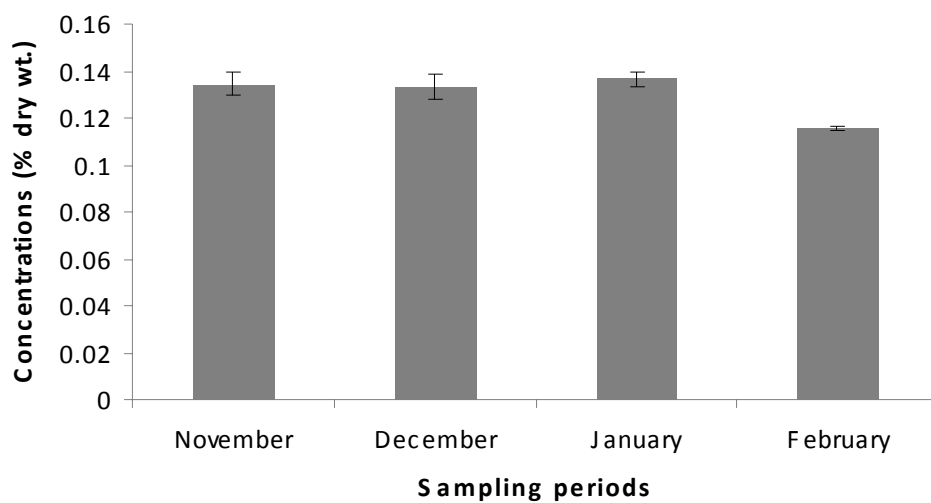


Fig. 8. Fluctuation in forage Mg²⁺ concentrations at different sampling periods.

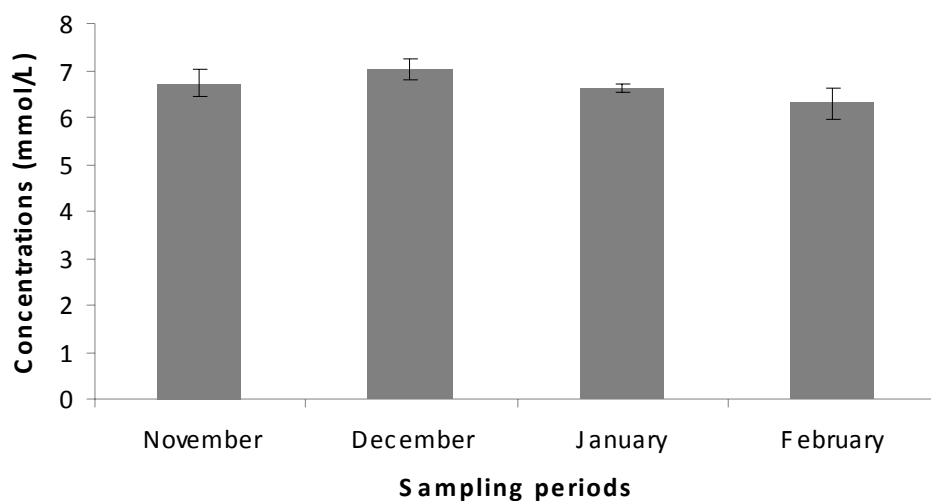


Fig. 9. Fluctuation in plasma Mg²⁺ concentrations at different sampling periods.

Plasma magnesium: Considerable variation in plasma Mg^{+2} were observed at sampling intervals accompanied with non significant effect ($p>0.001$) of different sampling intervals (Table 1). Mean plasma Mg^{+2} concentrations varied from 6.2 to 7.0 mg/dl. The higher plasma Mg level were found at sampling period 2nd and lowest Mg level at sampling period 4th. during our present study ans was higher than the critical value of 2.8 mg/dm observed by Grace *et al.*, (1983), but our findings corroborated to those of Fujihara *et al.*, (1992). Plasma Mg^{+2} levels observed during this study were higher than the values suggested by Orden *et al.*, (1999) and Gizachew *et al.*, (2002) for different livestock forms.

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(Received for Publication 26 March 2009)