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MONTHLY VARIATIONS OF MINERAL CONTENT IN SEMI-ARID RANGELANDS IN WESTERN MACEDONIA – GREECE

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Abstract

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The effect of growing season and altitudinal zone on herbage production and mineral element content (K, Na, Ca, P, Mg, Fe, Zn, Cu and Mn) in grazable material, were studied in herbage samples harvested from semi-arid pasturelands in Western Macedonia region - Greece. Sample collection was accomplished by clipping herbage biomass in situ at 2 cm above the ground. The statistical analysis showed an important effect of the harvest month and altitudinal zone on the herbage production, while it didn't seem to be affected by "month x altitude" interaction. Herbage production was positively correlated with K (r= +0.412) and Mn (r= +0.460) content, while there was no significant relation between herbage production and the other mineral contents assayed. Both macro minerals and trace minerals contents were affected significantly by the harvest month, except Ca, Mg and Mn. Only K and Ca contents were affected by altitudinal zone, while it was found that there was no influence of "month x altitude" interaction on both macro minerals and trace minerals. Some of the minerals studied (K, Ca, P and Mg) were seasonally sufficient in all altitudinal zones, while it was found significant deficiency of Na, Fe, Zn, Cu and Mn in the total area studied throughout the experimental period. The data suggest that a mineral supplement should be available during the grazing period in the studied pasturelands in available forms and proper ratios.

Key words: altitude, grazing season, rangelands, minerals, NW -Greece

Introduction

Traditional stockfarmings of ruminants (sheep and cattle) utilize to a high degree the Greek native grazing lands. Both, herbaceous and woody plants occur in north-western Greece grazing lands as they are considered important contributors to grazing animals' nutrition (Papachristou and Nastis, 1993a, 1993b; Espejo-Diaz, 1996). However, because of the intensive grazing of pasturelands, supplementary feed is often required to compensate animals for pasture deficiencies (McDowell, 1985). Grassland nutritional

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quality is affected by abiotic and biotic environmental factors including soil type, climatic regime, botanical composition and range improvement practices (Angell et al., 1990; Perez-Corona et al., 1998; Ramirez, 1999; George et al., 2001). On open rangelands, the quality and quantity of forage varies appreciably with climate and often leads to nutritional inadequacy (Ramirez, 1996).

Protein content and digestibility of dry matter have been emphasized as the main determinants of forage quality (Perez-Corona et al., 1998). However, much less attention has been paid to minerals even though they also influence forage quality and can depress feed intake when levels are low (Provenza, 1995).

All forms of life require inorganic elements, or minerals, to support normal life processes. (Poland, 2002). Furthermore, all animal tissues and all feedstuffs contain minerals in widely varying amounts and proportions. Unlike other nutrients, minerals cannot be synthesized by living organisms; therefore animals must acquire adequate amounts of required elements from their environment if survival and production goals are to be maintained. Livestock usually derive most of their dietary nutrients from the feed they eat, however significant quantities of minerals may be obtained from water, soil consumption and nonfeed contamination (Espinoza et al., 1991; Poland, 2002). Minerals that are required in relatively large amounts are called major or macro minerals and usually expressed as a percent of the diet. Minerals that needed in small amounts are classified as micro or minor minerals or trace elements. Trace elements are typically quoted in parts per million (ppm) or g kg^{-1} of the diet. (NRC, 1996; Ward and Lardy, 2005). The knowledge of estimated dietary mineral intake from both feed and water provides the basis for correcting deficiencies or adjusting for mineral excesses (Herd, 1997).

The purpose of this study was to evaluate grazable material mineral concentrations over a six-month period, May to October, 2004 and among two altitudinal zones for beef cattle and sheep moving from lower to higher altitudes during summer, in native semi-arid pasturelands in Western Macedonia region - Greece. The knowledge of herbage mineral content is judged useful for the mineral supplementation in the diet of grazing animals.

Materials and Methods

Study area

This study was conducted in the pasturelands of Municipality of Siatista, Western Macedonia - Greece (lat 40° 12′ to 40° 18′ N, long 21 ° 30′ to 21 ° 40′ E, 500-1600 m above sea level). The basic geological substrate of the whole research area is consisted of metamorphic rock textures (i.e. phyllites, gneisses and limestone) of the west Pelagonic geotectonic zone. The fertility of the soil varies depending on slope, exposure, degradation and vegetation. The mountain and topographic lie is quite tense and, in combination to the climate conditions that change from zone to zone, create an impressive variation of herbs from the lower to the upper zone. The climate approaches the Greek climatic conditions having as major characteristics long lasting and very hot summertime, soft winter and humidity in all seasons of year. The monthly average air temperature as well as rain precipitation in the decade 1992 – 2001 was 13.0°C and 33.7 mm respectively (HNMS, 2005).

The studied pasturelands cover 4,021 ha area, and they were graded as seasonal (Papanikolaou et al., 2002). That is, from 600-1200 m, they are grazed during spring and autumn, while over 1200m they are grazed in summer. Their productivity and readiness were mainly affected by climatic and soil conditions. These pasturelands are grazed mainly by sheep and beef cattle. Voluntary intake of DM was unlimited to grazing animals

Sampling and experimental analysis

The research work was conducted during the year of 2004, from May to October in two altitudinal zones (lower zone: 500-1000m, upper zone: over 1000m) of Siatista pasturelands. In October of 2003 ten experimental cages, sized 4m x 5m, fenced with metallic net 1.5 m high in order to obstruct free – range grazing, were placed in Siatista's pasturelands (five cages per zone). The cages were placed in representative areas of uniform botanical composition where sheep and beef cattle grazed.

Each experimental cage was divided into 36 equal plots. At the beginning of each month, from May to October, herbage biomass was collected from 6 of the 36 equal plots in each cage, using a 0.015m^2 quadrate. The herbage samples (grasses and forbs) were clipped *in situ* at 2 cm above the ground using hand sickles (Odum, 1971). Woody plants, shrubs or trees were not included in samples. The harvested forage samples (six quadrates per plot per month) were handled carefully to avoid soil contamination. The collected samples from each cage were stored in paper bags and weighed instantly in the field for fresh weight determination. After transportation to the laboratory all samples were oven-dried at 68^{o}C until reaching steady weight.

Samples were analyzed for potassium (K), sodium (Na), calcium (Ca), magnesium (Mg), phosphorus (P), iron (Fe), copper (Cu), zinc (Zn) and manganese (Mn).

An acid digest was prepared by oxidizing each sub-sample with a nitric/perchloric acid (2:1) mixture. Aliquots were used to estimate Ca, Na and K by flame photometry, P by spectrophotometeric methods (Khalil & Manan, 1990) and Mg, Mn, Fe, Cu and Zn by atomic absorption spectrophotometry (AOAC, 1999). Each sample was analysed in triplicate.

The data were analyzed statistically using univariate analysis of variance testing for the effects of harvest month, altitudinal zone and "month x altitude interaction", using the SPSS 12.0 (Kitikidou, 2005). It was also carried out an analysis of correlation of the variables and stepwise multiple regression. The significance level was assessed to $P < 0.05$, except for the cases of the existence of a different indication. All "±" symbols within this manuscript are associated with standard deviations.

Results

Herbage production showed a differentiation among subsequent or different months in both altitudinal zones. However, it presented similar fluctuation in production, which was increasing from May to mid-summer and then decreased till late October, showing its peak in July in the lower (942.90 ± 176.61 kg/ha), as well as in the upper zone (2,045.78 ± 1,223.53 kg/ha) (Figure 1).

The statistical analysis showed an important effect ($P < 0.05$) of both harvest month and altitudinal zone on the herbage production, while "month x altitude" interaction had no effect on the biomass production (Table 1). Herbage production had a negative relation ($P < 0.01$) to the altitudinal zone ($r= +0.447$) and

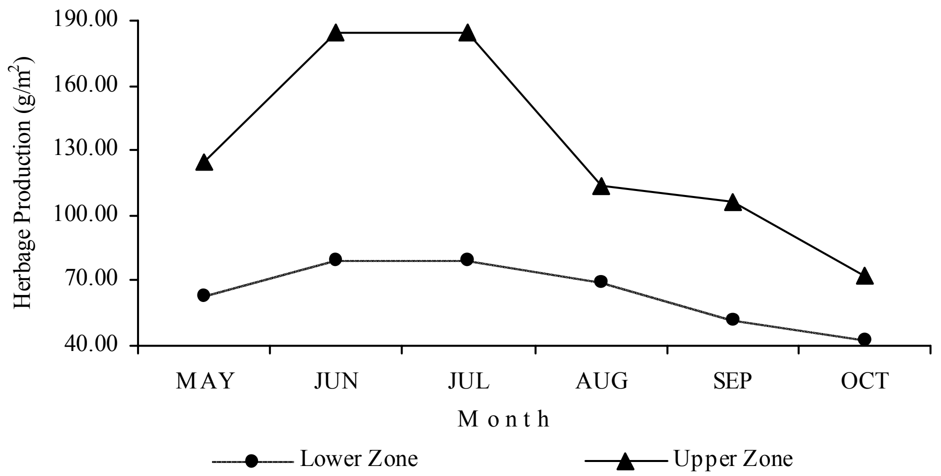

Fig. 1. Monthly variations of aboveground biomass production of Siatista's pasturelands at two different altitudinal zones (Means of five experimental cages per zone)

Table 1

P-values derived from univariate analyses of variance for production and mineral contents of herbage samples of Siatista's pasturelands NW Greece Main effects were months (May - Oct) and altitudinal zones (Lower-Upper). Shaded values are not statistically significant (P > 0.05)

Parameter	Month	Altitude	Month x Altitude
Herbage Production	0.049	0.001	**0.787**
	Macrominreals		
K	0.002	0.000	**0.976**
Na	0.002	**0.148**	**0.208**
Ca	**0.257**	0.025	**0.149**
P	0.000	**0.693**	**0.760**
Mg	**0.283**	**0.124**	**0.521**
	Trace elements		
Fe	0.000	**0.237**	**0.997**
Zn	0.000	**0.090**	**0.927**
Cu	0.000	**0.109**	**0.472**
Mn	**0.696**	**0.598**	**0.933**

K (r= +0.412) and Mn (r= +0.460) content (Table 2).

Mean potassium content was found to be 8.65 (± 3.92) and 16.90 (±6.45) g/kg DM in the lower and upper altitudinal zone respectively, during the whole experimental period. The lowest value measured in July, and the highest in May (Figure 2).

Mean Na content was found to be only 0.181 (±0.04) and 0.193 (± 0.03) g/kg DM in the lower and upper zone respectively. Na content affected significantly only by the harvest month (Table 1). Statistical analysis showed (P <0.01) that Na content had negative relation to the harvest month (r= -0.387), and positive one to the Mg (r= +0.380) and Fe (r = +0.354) content (Table 2). Variations of Na content of forage samples are shown in Figure 3.

Mean Ca content of herbage samples was found to be 8.60 (±1.85) and 10.29 (±3.27) g/kg DM in the lower and upper altitudinal zone respectively showing its peak in May (9.53 ± 2.75 g/kg DM) in the lower and in October (12.08 ± 2.93 g/kg DM) in the upper zone (Figure 4). Unlike K and Na, Ca content affected by altitudinal zone (P < 0.05) but it was found no effect by harvest month and "month x altitude" interaction (Table 1).

Mean P content of forage samples was found to be 2.33 (±0.9) g/kg DM and 2.38 (±0.8) g/kg DM in the lower and upper altitudinal zone respectively, showing its peak value during August in both altitudinal zones (Figure 5). Phosphorus affected significantly (P < 0.001) by the harvest month. Correlations between P content and the other minerals are shown in Table 2.

Pooled across months mean Mg content was 2.68 (±1.4) g/kg DM in the lower and 3.33 (±1.5) g/kg DM in the upper altitudinal zone. The peak Mg contents were found at the beginning of experimental period in May in both zones (Figure 6). It was found no effect (P > 0.05) from both harvest month and altitudinal zone on mg content of herbage samples (Tab.1).

Mean Fe content of forage samples were 31.792 (±6.88) and 33.583 (±7.75) mg/kg DM in the lower and upper altitudinal zone respectively. The peak values were 37.00 ± 3.37 g/kg DM in the lower and 39.75 ± 5.91 g/kg DM in the upper zone and they were found during May in both altitudinal zones (Figure 7). Fe content affected significantly (P < 0.001) by the harvest month only (Table 1).

Mean Zn content was found to be 22.125 (±7.88) and 24.542 (±6.20) mg/kg DM in the lower and upper altitudinal zone respectively, showing similar variation among subsequent months (Figure 8). Zinc content was affected significantly (P<0.001) only by the harvest month (Table 1). It was found a negative relation (P<0.001) of Zn with P (r = -0.468) and Cu (r = -0.490) content and a positive one with Fe (r = +0.478) content (Table 2).

Copper content of forage samples averaged 13.458 (±6.71) and 15.417 (±5.51) mg/kg DM in the lower and upper altitudinal zone respectively. Variations of Cu content are shown in Fig. 9.

Table 2
Correlation coefficients of measured parameters

	Month	Altitude	Herbage production	K	Na	Ca	P	Mg	Fe	Zn	Cu	Mn
Month	1	0										
Altitude	0	1										
Herbage production	0.9	0.154	1									
K	-0.099	0.227	0.002	1								
Na	-0,387[b]	0.021	-0.159	0,354[b]	1							
Ca	-0.052	-0.072	-0.024	0.038	0.257	1						
P	-0,317[b]	-0.179	-0.221	0.368[b]	0.217	0.16	1					
Mg	-0,276[a]	0.253	-0.068	0.245	0.380[b]	0.157	0.206	1				
Fe	-0,602[b]	0.106	-0.264	0,391[b]	0.354[b]	-0.058	0,305[a]	0.465[b]	1			
Zn	-0,580[b]	0.218	-0.173	-0.175	0.232	0.166	-0.013	0.186	0.179	1		
Cu	0.108	-0,413[b]	-0.105	-0.188	0.017	0.036	0.025	-0.066	0.065	0.015	1	
Mn	-0,304[a]	-0,307[a]	-0,275[a]	0.074	-0.003	0.035	0.425[b]	-0.056	0.216	0.081	0.174	1

Level of significance: [a] : P<0.05, [b] : P<0.01

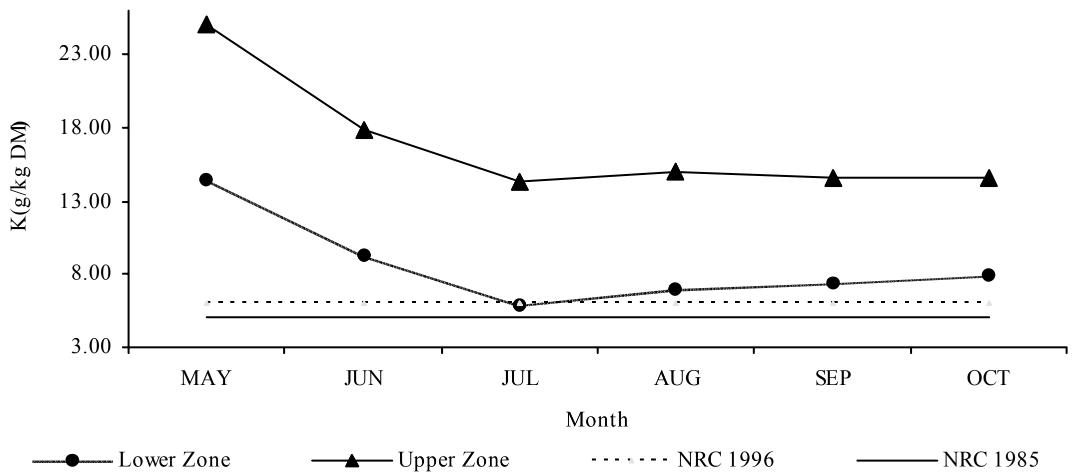

Fig. 2. Monthly variations of potassium (g/kg DM) of Siatista's pasturelands at two different altitudinal zone (Means of five experimental cages per zone)

Cu content affected significantly only by the harvest month but it was found no effect from the altitudinal zone and the "month x altitude" interaction (Table 1). Correlations between Cu and the other minerals are shown in Table 2.

The lower values of Mn content were found in October in both altitudinal zones (20.00 ± 5.35 mg/kg DM and 23.00 ± 6.48 mg/kg DM in the lower and upper zone, respectively) (Figure 10).

Mean Mn content of forage samples averaged 20.00 ± 5.35 mg/kg DM in the lower zone and 23.00 ± 6.48 mg/kg DM in the upper zone. It was found no effect (P > 0.05) by both harvest month and altitudinal zone.

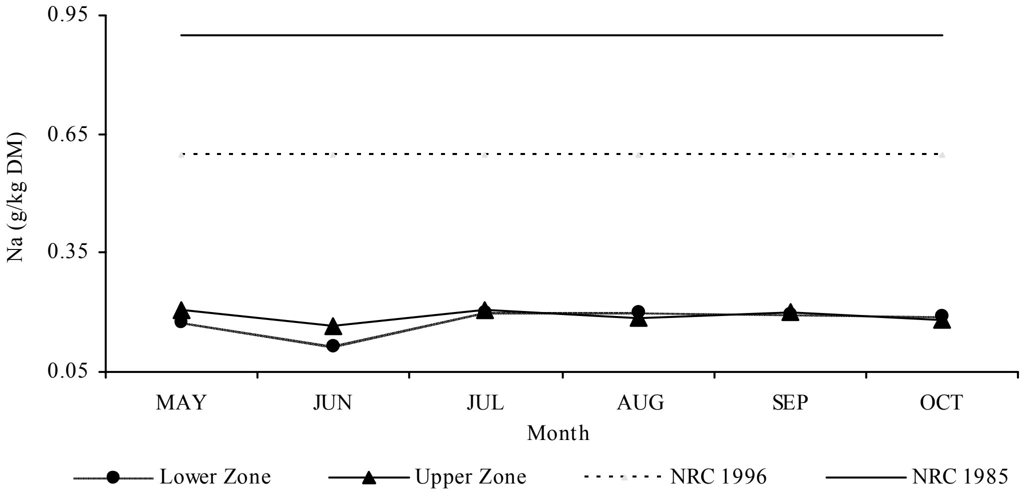

Fig. 3. Monthly variations of sodium (g/kg DM) of Siatista's pasturelands at two different altitudinal zone (Means of five experimental cages per zone)

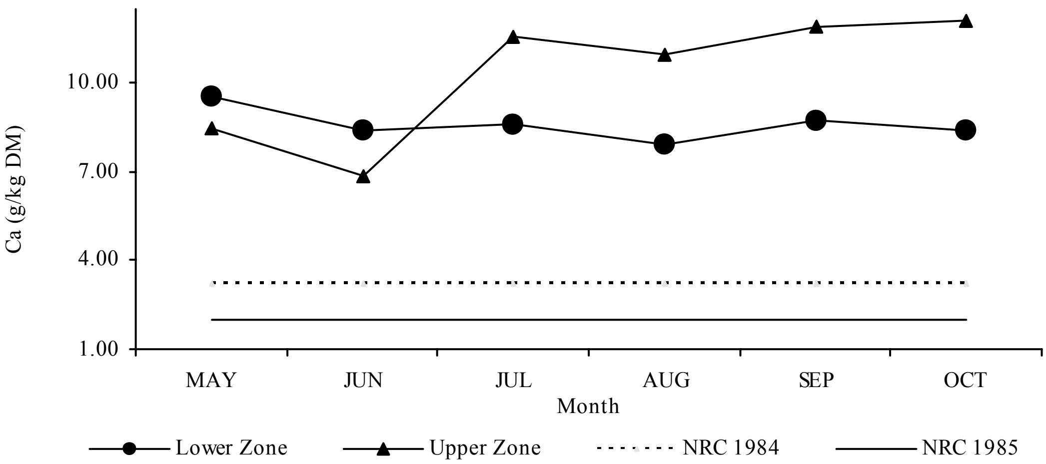

Fig. 4. Monthly variations of calcium (g/kg DM) of Siatista's pasturelands at two different altitudinal zone (Means of five experimental cages per zone)

Discussion

Herbage production of the studied pasturelands showed a differentiation among subsequent or different months in both altitudinal zones. However, it presented similar fluctuation in production, which was increasing from May to mid-summer and then decreased till late October. The typical shape of grassland growth is a sigmoid curve, increasing to a maximum and then decreasing (Perez-Corona et al. 1998). According to George et al., (2001), precipitation determines the beginning and the end of growing period of plants, while the air temperature usually determines the amount of aboveground biomass production during the vegetative period. In the experimental area, after July, because of the high temperature and low moisture in the soil, plants matured earlier than usual. In combination with the soil degradation, specifically in the lower zone, herbage production was decreasing rapidly. Herbage production was higher in the upper zone dur-

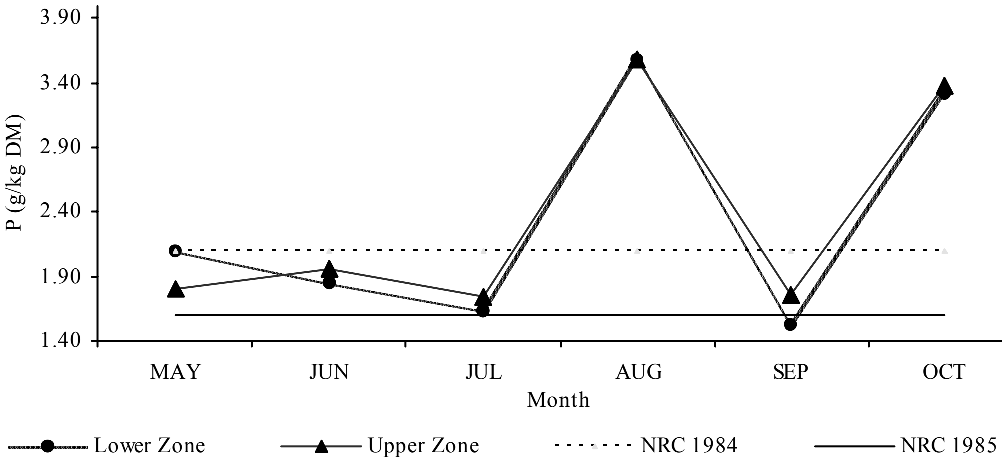

Fig. 5. Monthly variations of phosphorus (g/kg DM) of Siatista's pasturelands at two different altitudinal zone (Means of five experimental cages per zone)

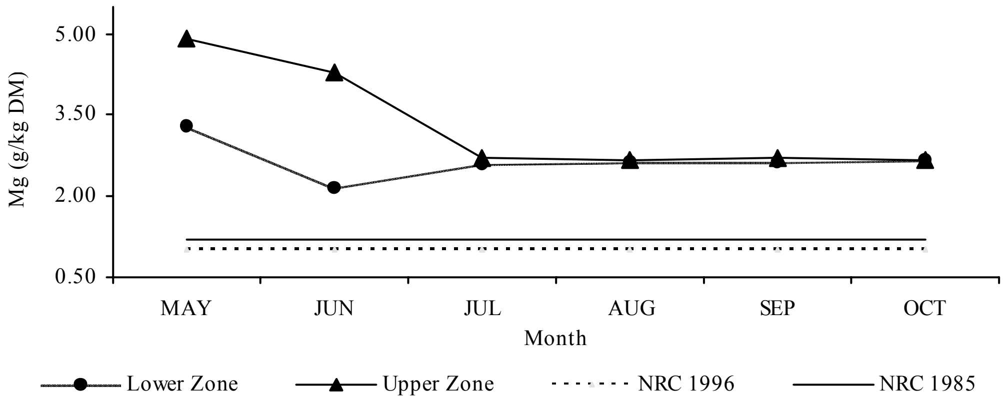

Fig. 6. Monthly variations of magnesium (g/kg DM) of Siatista's pasturelands at two different altitudinal zone (Means of five experimental cages per zone)

ing the whole experimental period (Figure 1). This indicates that the moving of sheep and cattle to higher altitudes, during summer, provides greater amounts of feed.

Potassium requirements range from 6 - 7 g/kg DM for all kinds of beef cattle (NRC, 1996) and from 5 - 8 g/kg DM for the sheep (NRC, 1985). The studied forage samples had higher K contents than those suggested for both cattle and sheep. Most of forage sources are relatively high in K (10 - 20 g/kg DM) (Ward and Lardy, 2005). So our results are in agreement with them.

Siatista's pastures Na contents were much lower than 0.6 - 0.8 g/kg DM for beef cattle (NRC, 1996) and 0.9 - 1.8 g/kg DM for sheep (NRC, 1985), in both altitudinal zones. This is in agreement with the findings that, native forages do not meet requirements of grazing animals (Grings et al., 1996; Greene, 1999). Although animals have considerable ability to conserve Na, prolonged deficiencies cause loss of appetite, decreased growth or weight loss, unthrifty appearance and reduced milking (McDowell and Valle, 2000), but supplemental salt can also stimulate weight gains among animals that are not showing signs of deficiencies

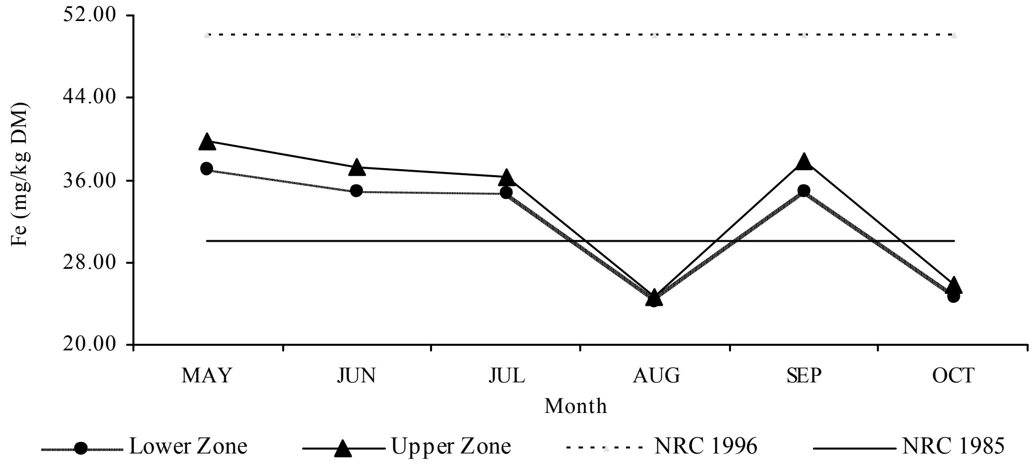

Fig. 7. Monthly variations of iron (mg/kg DM) of Siatista's pasturelands at two different altitudinal zone (Means of five experimental cages per zone)

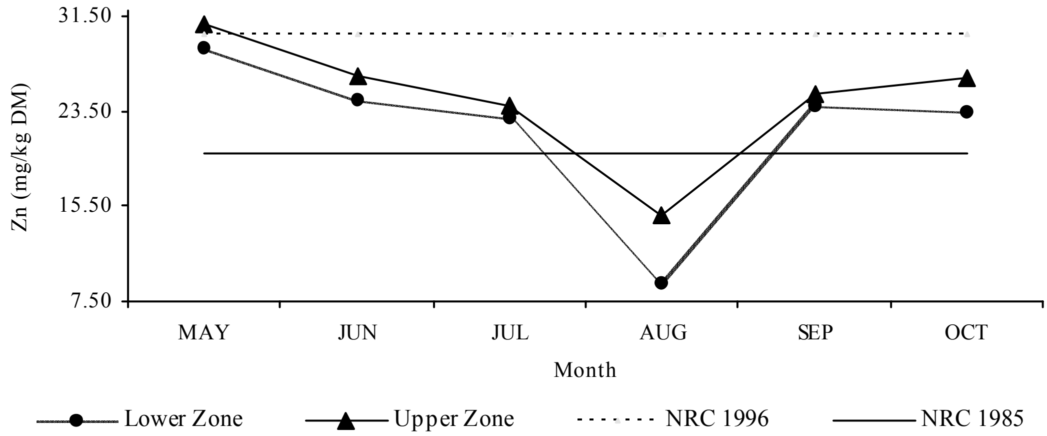

Fig. 8. Monthly variations of zinc (mg/kg DM) of Siatista's pasturelands at two different altitudinal zone (Means of five experimental cages per zone)

(Ganskopp & Bohnert, 2003).

For heifer calves with an average daily gain of approximately 0.6 kg, requirements ranged from 4.5 g Ca/kg DM for a 180 kg BW cow (introduction to the pasture in May) to 3.2 g Ca/kg DM for a 270 kg BW (end of grazing period in late October) (NRC, 1984). Correspondingly, to ewes that weigh approximately 50 kg the daily Ca needs of maintenance range from 2.0 to 8.2 g/kg DM (NRC, 1985). The forage samples of the study area had slightly higher levels of Ca for grazing sheep and much higher than beef cattle requirements. In Tanzania (Rubanza et al., 2005) as well as in Spanish grazing lands (Perez – Corona et al., 1998) Ca content was found to be, also, higher than that suggested by the NRC (1984) cattle requirements. Christoforidou (2004), reported from Chalkidiki peninsula, northern Greece that, in an over-grazed shrubland, Ca content varied from 14.4 to 7.4 g/kg DM for the period from April to October.

Phosphorus has been called the "master mineral", because it is involved in most metabolic processes (Rasby et al., 1998). On a worldwide basis, the most

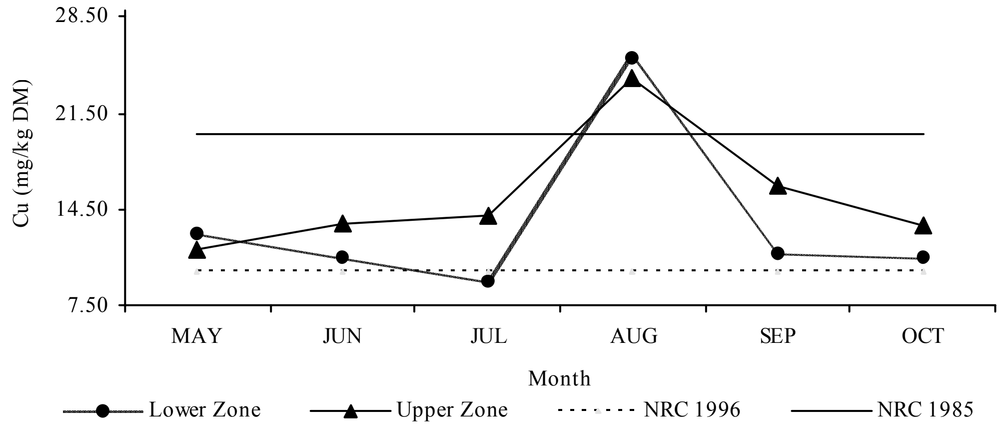

Fig. 9. Monthly variations of copper (mg/kg DM) of Siatista's pasturelands at two different altitudinal zone (Means of five experimental cages per zone)

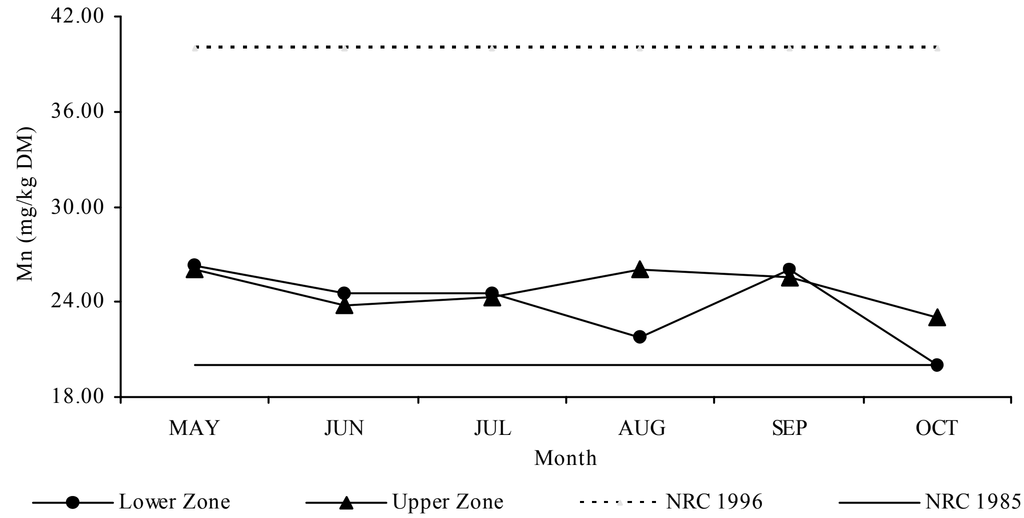

Fig. 10. Monthly variations of manganese (mg/kg DM) of Siatista's pasturelands at two different altitudinal zone (Means of five experimental cages per zone)

prevalent mineral deficiency among livestock is probably phosphorus (Underwood, 1981). For heifer calves with an average daily gain of approximately 0.6 kg, phosphorus requirements ranged from 2.4 g/kg DM for a 180 kg BW cow (introduction to the pastureland in May) to 2.1 g/kg DM for a 270 kg BW (end of grazing period in late October) (NRC, 1984). To ewes that weigh approximately 50 kg the minimum daily phosphorus requirements for maintenance is 1.6 g/kg DM (NRC, 1985). Forage samples met the minimum P requirements for beef cattle and sheep which graze in the studied pastures, in both altitudinal zones. Differences between the findings of this study and the literature could be partly explained by the higher soil P concentration and the adsorption by the roots.

Magnesium requirements for growing and finishing beef cattle averaged 1.0 g/kg DM (NRC, 1996) while for sheep range from 1.2% to 1.8 g/kg DM (NRC, 1985). The grazing land forages had higher levels of

Mg than those proposed by NRC for grazing animals. Mg deficiency is rare for ruminants grazing native forages (Greene, 1997, 1999).

The Fe levels in all forage samples were below the critical level of 50 mg/kg (Espinoza et al., 1991; NRC, 1996) for beef cattle. On the other hand they were slightly higher than 30 mg/kg DM (except August and September), the minimum requirements for sheep, which was suggested by NRC (1985), in both altitudinal zones (Figure 7). Differences of Fe content between our findings and literature could be partly explained by differences in soil Fe content, climatic conditions and locality. Forage Fe content is a function of forage species, soil Fe content, nature and type of soil on which forages are grown (McDowell, 1992; Rubanza et al., 2005). Iron deficiency is rare in grazing cattle due to a generally adequate content in forages (McDowell et al., 1984). However, under Florida conditions, Fe deficiency in cattle grazing on sandy soils has been reported (Becker et al., 1965).

Zn contents of forage samples were slightly lower than 30.0 mg/kg DM, suggested by (NRC, 1996) for beef cattle. On the contrary, Zn content met the minimum requirements (20 – 33 mg/kg DM) of sheep (NRC, 1985). Only in the upper zone, in May, the Zn content reached the level of 30.0 mg/kg DM (Figure 8). Flemming (1963) noted that zinc content varies considerably among components of grass plants and found leaf/stem/flower concentrations of 20, 15, and 36 mg/kg, respectively. Zinc deficiencies can cause parakeratosis (inflamed skin around nose and mouth), stiffness of joints, alopecia, breaks in skin around the hoof, and retarded growth (Ganskopp & Bohnert, 2003). These deficiencies could be improved through supplementation with Zn sources.

Copper content had higher values than 10 mg/kg DM suggested for beef cattle (NRC, 1996). Cu requirements for sheep range from 20 to 33 mg/kg DM (NRC, 1985). Cu content in the studied pasturelands were much lower than the minimum requirements for sheep (Figure 9). With the exception of P, Cu is the most common mineral deficiency for grazing ruminants in the world (McDowell, 2003). Differences of Cu content with other areas could be partly explained by genotypic differences, vegetative parts, stage of maturity, levels of available Cu in the soil and soil pH.

Mean Mn contents of forage samples were found to be lower than 40 mg/kg DM suggested by NRC (1996), for beef cattle. On the contrary it was adequate to sheep nutrition because it met the minimum requirement of 20 mg/kg DM (NRC, 1985). Deficiency of manganese in cattle grazing under natural conditions had been reported in some areas in United States (Hale and Olson, 2000). To avoid perturbation of cattle productivity, Mn supplements should be available during the grazing period in the experimental area.

Conclusions

• The results of this study showed that the harvest month had a significant effect on herbage production and the most of minerals studied. On the contrary only K, Na and Ca affected by the altitudinal zone, while it was found no effect by the “month x altitude” interaction on both herbage production and mineral contents.

• K, Ca, P and Mg was found to be adequate for both cattle and sheep nutrition requirements, while Na was deficient for all ruminants.

• Fe, Zn and Mn were deficient for beef cattle nutrition but they could meet sheep requirements. On the contrary Cu was deficient for sheep but adequate for beef cattle.

• Productivity of grazing ruminants in studied pasturelands could be improved through supplementation with mineral sources. We suggest that a mineral supplement of Fe, Zn and Mn in cattle, Cu in sheep and Na both sheep and cattle diets should be available during the grazing period in the experimental area.

More research is needed to determine the seasonal variation of mineral content of herbage in the study area for better decision of mineral supplementation

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