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SEASONAL VARIATION OF NUTRIENTS IN HYPERRHENIA GRASS FROM LIEMPE FARM IN LUSAKA, ZAMBIA.

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This paper is published in memory of the main author Professor Nathan Siulapwa who died on 16th of January 2016 just after finishing compilation and editing of this manuscript. May His Soul rest in Eternal Peace.

ABSTRACT

Introduction: *Herbaceous species play an important role in ruminant feeding worldwide. The nutrient balance of an animal is reliant on the nutrient requirements of the animal, the nutritional quality of feedstuffs, the amount consumed and its digestibility. Furthermore, the productive value of a pasture is mostly determined by the amount consumed by an animal and contribution of the required nutrients. In Zambia, forage species still serve as source of essential elements for grazing animals. However, little information is available on the nutrient status of grazing animals and of the forages upon which they subsist. Knowledge of the nutritional quality of rangeland forages is important to sustain satisfactory growth and reproduction of livestock. Such awareness further assists in attaining proper stage of utilization, helps in envisaging the nutrient deficiencies and suggests supplemental requirements for animals This study was thus planned to investigate the seasonal variation of nutrients in grasses from Liempe farm in Lusaka, Zambia.*

Materials and Methods: *This study was conducted at Liempe farm owned by University of Zambia, Lusaka, Zambia between November 2009 to December 2010.Proximate and mineral content analysis where done according to the standard methods. One way Analysis of Variance (ANOVA) was used in analysing the data.*

Results and Discussion: *The results indicate that Hyperrhenia grass harvested during the hot season had a higher content of dry matter (74.2 ± 10.6%) than that obtained in the cold (50.8±2.7%) and rainy season (31.7±8.1 %), P<0.05.Crude fibre content was also higher in the hot season than cold and rainy season. However there was significant difference in fibre content between hot and the cold seasons P>0.05. Crude protein and Nitrogen content was higher in the rainy season (2.9±0.9 %) than cold (2.2±0.4 %) and hot season (1.2±0.1%). There was a significant difference in crude protein content among all the three seasons (P<0.05). Carotene content was significantly higher during the rainy season (9.2±0.8 mg/kg) than cold (2.8±0.9 mg/kg) and hot season (0.2± 0.01 mg/kg). Mean phosphorous content was higher in the rainy season (0.35±0.14%) than the hot season (0.15±0.03%) and there was no significant difference in phosphorous content between cold and rainy season (P<0.05). The highest content of potassium and calcium in the grass analysed was found in the hot season than the cold and rainy season. There was no significant difference in potassium content between grass harvested in the cold and rainy season P>0.05. Magnesium content was found to be higher during the cold season (0.66±0.23 %) than the rainy season (0.41±0.05 %).There was no significant difference in magnesium content between the grass obtained during the hot and cold season. In terms of copper content no significant difference was obtained among the three seasons (P>0.05). There was a significant difference in iron content across all the three seasons with the rainy season having the highest iron content (3.2±0.9 mg/kg) and hot season having the lowest iron content (1.9±0.1 mg/kg). Zinc content was higher in the rainy season (0.38±0.18 mg/kg) than the cold and hot season (0.31±0.08 mg/kg) and*

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(0.22±0.05mg/kg) respectively. However there was no significant difference in Zinc content between the grass harvested in the cold and rainy season.

Conclusion: *The results show that the nutritive values of hyperrhenia were greatly affected as a result of seasonal variability and that seasonality need to be taken into consideration when harvesting the grass so as to obtain maximum nutrients.*

Key words: Hyperrhenia grass, nutrition, forage, crude protein, Calcium, Iron

INTRODUCTION

Ruminant livestock subsector in Zambia contributes about 35% of the national agriculture output (FAO, 2005). Generally in Zambia, productivity per animal is very low (Chilonda et al 2005). Herbaceous species play an important role in ruminant feeding worldwide (Arzani et al., 2006). Beever et al. (2000) have argued that the feeding quality of native forages is usually determined by its nutrient content and voluntary intake of animals. Feed quality refers to the amount of nutrient that an animal can get from a feed in the shortest possible time. According to Hussain and Durrani (2009), the nutrient balance of an animal is reliant on the nutrient requirements of the animal, the nutritional quality of feedstuffs, the amount consumed and its digestibility. Furthermore, the productive value of a pasture is mostly determined by the amount consumed by an animal and contribution of the required nutrient (energy, protein, minerals and vitamins) for maintenance and production (Asaadi and Yazdi, 2011). Under arid conditions, the nutritional quality of herbaceous species is typically influenced by the seasonality of rainfall. The effect of seasonality on the nutritional quality of indigenous forage species has been widely documented (Alemayehu, 2006; Sisay, 2006). Others (Sisay, 2006; Desalew, 2008) argued that differences in the nutritional quality of forages can influence the value of feed resources.

Many tropical grasses have been studied in both laboratory and feeding practices. The nutritive value of forages is a result of the combined effects of genetic and environmental factors. The genetic factors include species, strain within species, type of growth and the response to environmental factors. The nutritional quality of herbaceous plants is known to be influenced by climate (Arzani et al., 2008), soil nutrient status (Tessema et al., 2011), grazing pressure (Henkin et al., 2011) and management aspects (Van der Westhuizen et al., 2005). Previous study showed that nutritive value of legumes assessed by nutrient digestibility and metabolizable energy content greatly varied among the species and it was higher in rainy season than that in dry season (Evitayani et al., 2004). According to Nitis et al. (1980), the botanical composition of the forage fed during wet season consists 35% grass and 65% shrub and tree fodders, while during dry season it consists 6% grass and 94% shrub and tree fodders. This is as a result of the dependence of grass and legume nutrient contents on the amount of moisture found in the soil in which the forage plants grow (McDowell et al., 1983). It has also been shown that when balanced diet are fed to animals, their performance or productivity is enhanced and they are better equipped to fight diseases as a result of improved immune system (McDonald et al., 1995). In Zambia, forage species still serve as source of essential elements for grazing animals. However, little information is available on the nutrient status of grazing animals and of the forages upon which they manage to survive. The nutrient status of these forages is a function of multiple factors which interact with one another to produce varied effects (Eze, 2010). It is therefore vital to investigate how seasonal variations influence the nutrient components of forage grasses in Zambia. A recent literature (Ganskopp and Bohnert, 2001) has shown that knowledge of the nutritional quality of rangeland forages is important to sustain satisfactory growth and reproduction of livestock. Such awareness further assists in attaining proper stage of utilization, helps in envisaging the nutrient deficiencies and suggests supplemental requirements for animals (Arzani et al., 2006). This study was thus planned to investigate the seasonal variation of nutrients in grasses from Liempe farm in Lusaka, Zambia.

MATERIALS AND METHODS

The study was conducted at Liempe farm owned by University of Zambia, Lusaka, Zambia between November 2009 to December 2010. This site is dominated by arid and semi-arid climate that is characterized by moderate temperature and bimodal type of rainfall. The annual rainfall is about 1078mm, while the mean annual temperature varies from 19 to 24°C. The rangelands have perennial herbaceous forage (Hyperrhenia grass species), interrupted in place by woody vegetation dominated by Acacia species.

Grass Sampling Procedure

Samples of hyperrhenia grass species were cut monthly using a sickle at 2 inches from the ground level. The samples were collected in three seasons viz: during the rainy season (November to April 2009/2010) and cold season (May to July, 2010) and hot season (August to November, 2010). After collection, samples were dried at 105°C for 48 hours, and then ground to a fine powder with a cyclotec 1093 grinding mill (Foss, South Africa) and packed in airtight polythen bags for storage before they were finally subjected to analysis.

Proximate analysis

Dry matter (DM) and crude fibre (CF) content of grass samples were determined according to the official method of Analytical Chemists (AOAC, 1994). The crude protein content was determined using macro kjeldahl method as reported by Kirk *et al*. (1991). The gram nitrogen obtained was multiplied by 6.25 to obtain the crude protein content calorimetrically using the spectronic 20 (Gallenkamp, UK) (Kirk and sawyer, 1991) with KH_2PO4 as the standard. Carotene was analysed by dissolving samples in 40 cm3 of ethanol and 2.5 g of potassium hydroxide dissolved in 2.5 cm3 of water added. The mixture was heated to reflux for 30 minutes, cooled and extracted with hexane until the extract was colourless. The hexane extracts were washed with water and then dried over sodium sulphate. The hexane was then removed on a rotary evaporator and the sample stored under nitrogen. All operations were performed in a dark room.A suitable volume (e.g. 10 cm3) of the test solution was pipette into a glass column prepacked with a mixture of activated magnesia (Sea Sorb 43) (Fisher Scientific Co or Sigma Chemical Co) and diatomaceous earth (Hyflo Super Cel) (Fisher Scientific Co), in the ratio of 1:3. Carotenes were eluted from the column with approximately 80 cm3 of 10% (v/v) acetone in hexane. The solvent was changed to 20% acetone in hexane and a further coloured fraction eluted, which contained xanthophylls. The eluate was evaporated on a water-bath with the aid of a stream of nitrogen and made up to a suitable volume (e.g. 10 cm3) with hexane. The absorbance of the solution was read in a spectrophotometer at 450 ran and the concentration of carotenes calculated by comparison against a calibration curve prepared with the β-carotene standard.(FAO,1992).

Chemical analysis of elements

Grass samples were processed by wet digestion using nitric acid and perchloric acid. K, Ca, Na and Mg were measured in the filtrate after diluting samples with strontium chloride. The respective elements were read on an atomic absorption spectrophotometer (Perkin-Elmer, Model 2380). Phosphorous (P) was determined on spectrophotometer at 882 nm after developing a molybdenum blue colour by reacting ammonium molybdate in acid solution with ascorbic acid.

RESULTS AND DISCUSSION

Table 1: Proximate and carotene analysis of natural grass at Liempe Farm of the University of Zambia

SEASON	Dry Matter (%)	Crude Fibre (%)	Crude Protein (%)	Nitrogen (%)	Carotene (Mg/Kg)
Hot	74.2 ± 10.6^a	47.9 ± 1.3^a	1.2 ± 0.1^a	0.18 ± 0.01^a	0.2 ± 0.01^a
Cold	50.8 ± 2.7^b	44.0 ± 01.3^a	2.2 ± 0.4^b	0.36 ± 0.07^b	2.8 ± 0.9^b
Rainy	31.7 ± 8.1^c	35.4 ± 3.7^b	2.9 ± 0.9^c	0.46 ± 0.15^c	9.2 ± 0.8^c

All values expressed as means ± SE on dry weight basis.

Values on the same column followed by the same letter are not significantly different ($p > 0.05$)

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Fig 1a: Mean Dry matter content

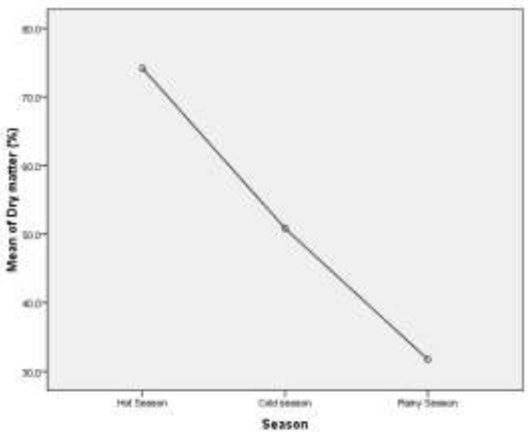

Fig 1b: Mean crude fibre content by season

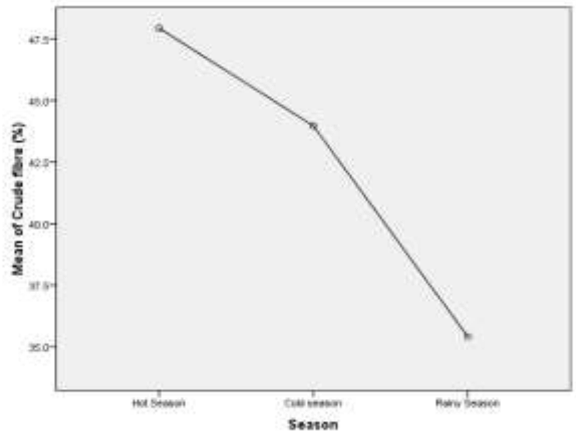

Fig 1c: Mean crude protein content

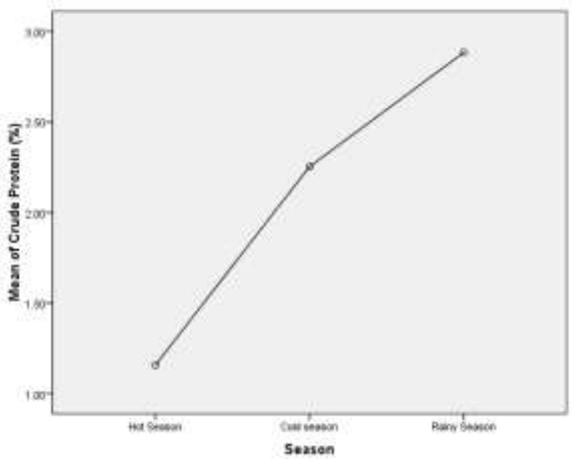

Fig 1d: Mean nitrogen content by season

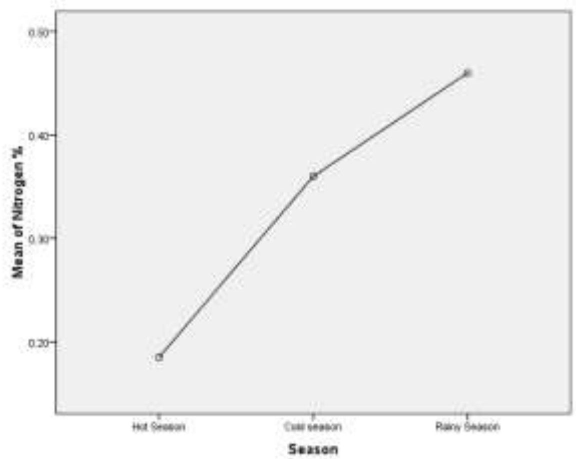

Fig 1e: Mean carotene content by season

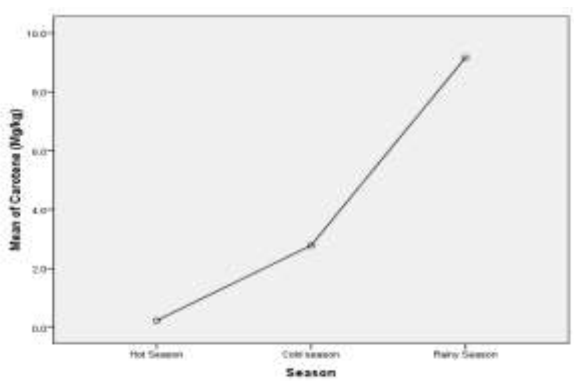

Table 2: Mineral Composition of natural grass at Liempe Farm of the University of Zambia

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Season	P (%)	K (%)	Ca (%)	Mg (%)	Cu (Mg/kg)	Fe (Mg/kg)	Zn (mg/kg)
Hot	0.15±0.03[a]	1.34±0.09[a]	2.18±0.02[a]	0.65±0.07[a]	0.05±0.01[a]	1.9±0.1[a]	0.22±0.05[a]
Cold	0.35±0.09[b]	0.89±0.65[b]	2.00±0.99[a]	0.66±0.23[a]	0.09±0.01[a]	2.4±0.1[b]	0.31±0.08[b]
Rainy	0.35±0.14[b]	0.78±0.4[b]	1.06±0.3[b]	0.41±0.05[b]	0.13±0.10[a]	3.2±0.9[c]	0.38±0.18[b]

All values expressed as means ± SE on dry weight basis.

Values on the same column followed by the same letter are not significantly different ($p > 0.05$

Fig 2a: Mean phosphorous content by season

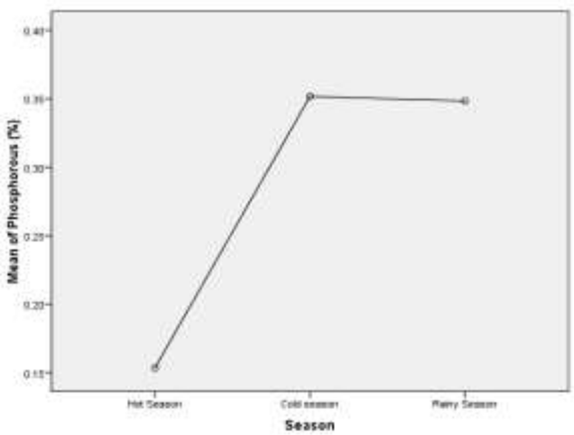

Fig 2b: Mean Potassium content by season

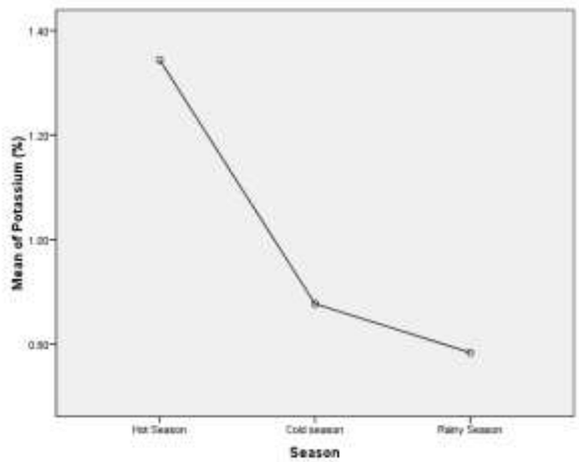

Fig 2c: Mean Calcium content by season

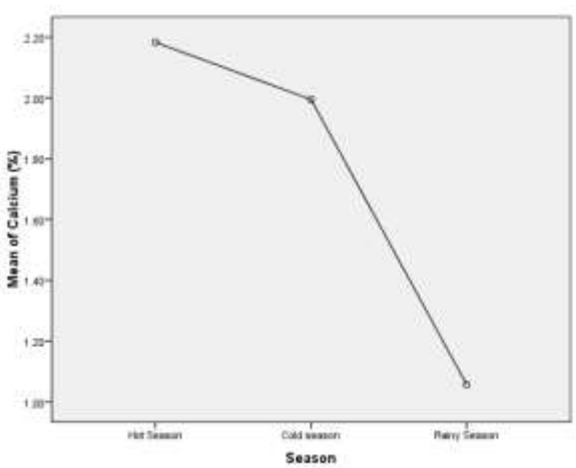

Fig 2d: Mean Magnesium content by season

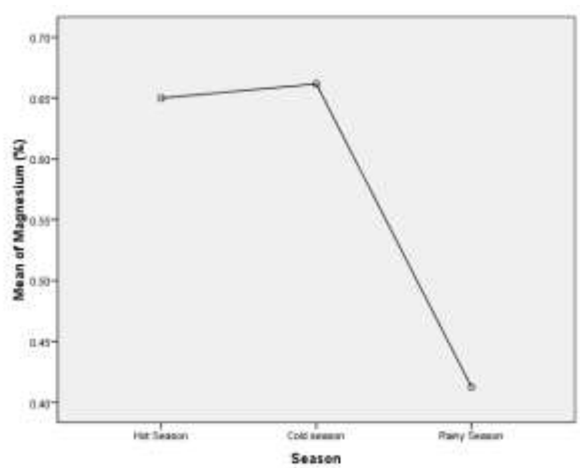

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Fig 2e: Mean copper content by season

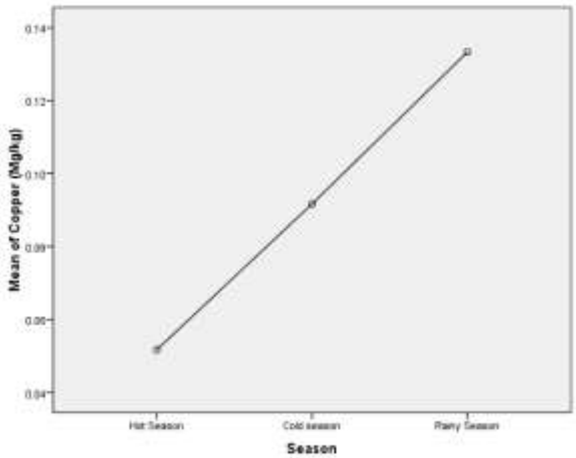


Fig 2f: Mean iron content by season

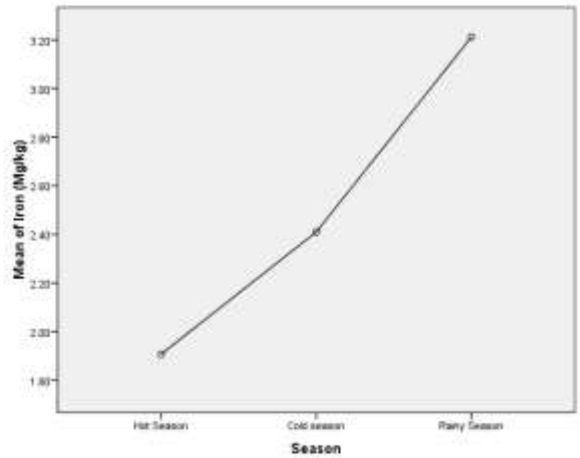
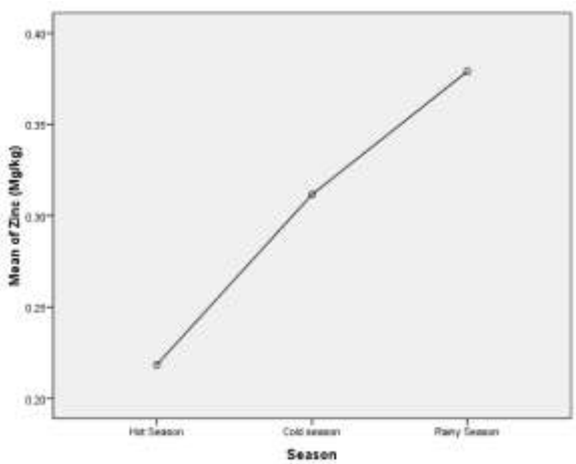


Fig 2g: Mean Zinc content by season



The variations in nutritional quality of hyperrhenia species between the rainy, cold and hot dry season in this study site are presented in Table 1 and Table 2 and Fig 1a-1e/Fig 2a-2g. The results show that the nutritive values of hyperrhenia were greatly affected as a result of seasonal variability. Dry matter content was significantly higher in the Hot season than cold and rainy season (P<0.05), with the rainy season having the lowest dry matter content. There was a significant difference between Crude fibre content in the hot season and rainy season, with the hot season having the highest amount. However, crude fibre content between hot and cold season was not significantly different (P>0.05). The highest crude protein, Nitrogen and carotene content was found in the rainy season and the lowest was in the hot season. The difference in the crude protein, Nitrogen and carotene content across the three seasons was very significant (P<0.05). Tolera et al. (1999) indicated that more than 90% of the feed for ruminant animals were derived from native forages, where nutritional status may be affected by various factors. Seasonality, species specific feed resources,and site differences are known to be the major factors affecting the nutritive value of native pasture (Mahala et al.,2009).

In the present study, the nutritive value of hyperrhenia species such as crude protein was considerably influenced by seasonality. This is also related to the proportion of crude protein and the structural fibre constituents (lignin, cellulose and hemi-cellulose) in the herbage between the rainy, cold and dry seasons. Da Silva (2011) has reported that the nutritive value of rangeland pastures can be affected by seasonality and variation in temperature across a wider landscape of arid regions, suggesting that higher temperature promotes the development of fibre in plants; higher temperature also promotes the rapid conversion of photosynthetic products in the cell wall components of a particular plant species. Arzani et al., (2008) have also shown that seasonal variation, inherent species type, sites potential and soil characteristics are important in driving the dynamics of herbage quality.

The present results supports the view that seasonal variations had a significant influence on the nutritive value of herbaceous plants, which is also in accord with various studies (Rubanza et al., 2006;Sisay,2006; Desalew,2008). Fibre of hyperrhenia was greatly increased during the dry season. Generally, the level of crude protein was adversely affected in the dry season, which is also in agreement with other workers (Sisay, 2006; Desalew, 2008). The structural constituents (eg lignin,cellulose and hemi-cellulose) of plant materials usually increase with stage of maturity of species.Overall,the crude protein content of herbaceous species is higher at a young stage than at mature stage (Singh et al., 1997; Mahala et al.,2009). In the present study, it was found that as the stage of maturity advances, the crude protein content of hyperrhania species declined drastically with corresponding increase in fibre, which is in agreement with the report by Mahala et al., (2009),who noted that crude protein content of a forage is inversely proportional to its fibre content. The nutritional content of any forage is dependent on its nutrient content such as protein, which is essential for the growth, development and production status of ruminant animals. The results indicate that the crude protein content of herbaceous plants during dry season is far below the critical level,based on the findings of Mahal et al., (2009). This may reflect the higher proportion of structural fibers with increased stage of maturity (Mahala et al.,2009) or due to fluctuations in species composition linked to the extreme variability of climate (i.e.temperature and precipitation) and leaf to stem ratio, as well as sugar dislocation (Beever et al., 2000). The nutritive content of any forage is dependent on its nutrient content such as protein, which is essential for the growth, development and production status of ruminant animals.

In the current study, carotene content was higher in the rainy season than the dry seasons (Cold and hot). The results are in agreement with Allardyce et al.(2011,who reported higher carotene content in the rainy season than the dry hot season. Reynoso et al. (2004) reported that β-carotene amount in green forages within the same plant species depends on temperature and solar radiation. The same authors also showed that forage β-carotene and α-tocopherol levels are higher in cool and humid summers than in dry and hot summers because of a higher proportion of leaves. Ballet et al. (2000) reported that the amount of β-carotene and vitamin E in fresh pasture is influenced by both climatic conditions and the origin and the maturity stage of forage, although the ratio of leaf to stem is the main factor responsible for the antioxidants (AO) variations. Carotenoids are unique constituents of a healthy diet and play an important role in the network of antioxidant vitamins and phytochemicals. They are good blue light filters and are efficient quenchers of singlet oxygen and excited triplet state molecules. The lipophilicity of carotenoids determines their subcellular distribution; they are enriched in membranes and other lipophilic compartments. Taken together, this makes them suitable photoprotectants, not only for plants but also for humans.

In the present study, phosphorous content was found to be higher during the rainy and cold seasons than the hot dry seasons. There was no significant difference in Phosphorous content during the cold and rainy season. The concentration of P in whole plants have been reported to decrease with advancing maturity in tropical grasses, but Minson, 1990, found little difference in content of P between leaf and stem. Powell *et al.* (1978) also showed that the apparent absorption of P in plants decreased with plant maturity in temperate grasses. Phosphorus content normally parallels that of protein in regard to seasonal changes. Stoddart, 1941 reported decreased Phosphorus and magnesium in *Symphoricarpos rotundif olius* with advancing season. Deciduous shrubs in California also showed a marked decrease in phosphorus content toward maturity (Gordon and Sampson, 1939). Reid and Horvath (2000) found that Brome grass, timothy and alfalfa grown at warm (32-24°C day-night) temperatures contained higher concentrations of P than those grown at lower temperatures (18-10°C). The herbage P concentration changed with season but also varied with species. For young ryegrass leaves, P concentration was highest in spring and lowest in autumn before rising again at the last harvest (7th of May in New Zealand) (Reay and Marsh, 2004). In young leaves of red clover, P content decreased from spring to late summer (Reay and Marsh, 2004). For herbage consisting of grasses, clovers and other species in New Zealand, Metson and Saunders (2001) reported maximum levels of P in late autumn to late winter (May or June to August or September), and minimum levels in summer (December to January or February). Reid and Horvath (2000) found that Brome grass, timothy and alfalfa grown at warm (32-24°C day-night) temperatures contained higher concentrations of P than those grown at lower temperatures (18-10°C). The herbage P concentration changed with season but also varied with species. For young ryegrass leaves, P concentration was highest in spring and lowest in autumn before rising again at the last harvest (7th of May in New Zealand) (Saunders and Metson, 2001; Reay and Marsh, 1976). In young leaves of red clover, P content decreased from spring to late summer (Reay and Marsh, 2004). For herbage consisting of grasses, clovers and other species in New Zealand, Metson and Saunders (2001) reported maximum levels of P in late autumn to late winter (May or June to August or September), and minimum levels in summer (December to January or February).

Our study showed that on average K content was higher during the hot season than in the rainy season. This was in contrast to many studies. Stuart *et al.*, (1995) reported increased K content with increasing air temperature in plants like crested wheatgrass (Stuart *et al.*, 1995), brome grass, perennial ryegrass, timothy and alfalfa (Reid and Horvath 2000) during growth. Seasonal changes of K concentration seem to exist in grasses and clovers (McNaught *et al.*, 1994), but trends are not very clear, with minimum levels in early summer and peaks in early autumn and again in winter (Metson and Saunders, 2001).

Calcium content was found to be higher in the hot season than the cold and rainy season. There was a significance difference in the calcium content between the hot and rainy season ($P<0.05$). An increase in ambient temperature tends to increase the Ca content of herbage (Evans *et al.*, 2006;) Brome grass (*Bromus inermis leyss.*) and timothy (*Phleum pretense L.*) cultivated at warm (32–24°C day–night) temperatures contained more Ca compared to when grown at lower temperatures (18–10°C day-night) (Reid and Horvath, 2000). In alfalfa, however, higher temperatures resulted in decreased concentration of Ca in four temperature regimes (32–27, 27–21, 21–15, and 15–10°C day–night) (Smith, 2001). The concentration of Ca in herbage showed marked seasonal changes. In young ryegrass (*Lolium*) leaves, the content of Ca was lowest in the spring and rose about two-fold to a maximum in early autumn before falling to a low level in late autumn (Reay and Marsh, 2001). Ryegrass and clover (*Trifolium*) leaves were found by McNaught *et al.* (1994) to have their maximum contents of Ca in the late summer. In New Zealand, Ca concentration in a herbage mixture (grasses, clovers and other species) showed a maximum value in summer and minimum in late winter to early spring (Metson and Saunders, 2001 However, Loneragan *et al.* (2000) reported that herbs and all legumes except lupins (*Lupinus*) maintain high Ca concentrations throughout the growing season. By contrast, in grasses and especially in cereals, Ca concentrations were low in young plants and declined further as season progressed (Loneragan *et al.*, 2000). The fact that calcium content increased with maturity was explained on the basis of the increased amount of cellular material which is composed principally of this element. McNaught *et al.* (1994) has suggested that the late-season increases in calcium and ash may be attributed to dust accumulations. Minson (1990report no seasonal trend in calcium content. These reported differences in results seem to indicate that there are several interrelated and poorly understood factors which influence the calcium content of shrubs.

Magnesium content was significantly higher in hot and cold than in rainy season. There was no significant difference ($P>0.05$) in magnesium content between the hot and cold season. A general decline in concentration of minerals has been noted with increased plant maturity, but the concentration of Mg in plants was noted to increase with advancing maturation (Minson, 1990), probably due to the lower levels of interfering compounds like N and K in the more mature herbage. A review study found that the concentration of Mg tended to increase with increasing air temperature in plants like brome grass and timothy during growth (Reid and Horvath, 2000). However, the concentration of Mg was found to decrease in crested wheatgrass (*Agropyron desortorum*) (Stuart *et al.*, 1995) and alfalfa (Reid and Horvath, 1980), when air temperature increased. Mg concentration of herbage showed large seasonal variations in ryegrass and clovers (McNaught *et al.*, 1994; Reay and Marsh, 2001).

Copper content in the hyperrhenia grass analysed ranged from 0.05 to 0.13mg/kg across all the seasons and no significance difference was found amongst the seasons (P>0.05). Asira et al.(2013) reported Copper content in the experimental grass species was higher in rainy season than dry season. There was significance (P<0.05) difference in months, of copper content in guinea grass, whereas non exist in giant star grass.

It has been reported that increased plant maturity resulted in a decline in Cu concentration of many forage plant species (Minson, 1990). The reduction in Cu content with increasing plant maturity of forage crops is probably caused by the concomitant decrease in proportion of leaves and lowering of Cu concentration in stems. Content of Cu in forage generally declined during the growing season (Minson, 1990) and at the beginning of a rainy period (Pott *et al.*, 1989). In northeastern Mexico, Cu content was higher during summer than in other seasons in ten browse species (Ramírez *et al.*, 2006). In North Florida, USA, Cu deficiency in cool season pasture forages was found during the late fall, winter, and spring grazing seasons (Chelliah *et al.*, 2008). Suttle (2010) reported increased temperatures and advancing plant maturity as causes for low Cu concentration in forage.

Both Iron and Zinc content were higher in the rainy season than hot and cold season. The difference in iron content across all the seasons was very significant (P<0.05), while there was no significant difference in zinc content between the cold and rainy season. Forages are naturally rich in Fe due to well supplied soils. Grass grown on soils derived from serpentine soils usually have abundant Fe content, but Fe values above 300 mg/kg DM reflect soil contamination of the sample, rather than intrinsic iron in the forage. Such adventitious Fe can depress the availability of Cu to the ruminant (Givens *et al.*, 2000).

Brome grass, timothy and alfalfa grown at warm (32-24°C day-night) temperatures contained higher concentrations of Fe compared to the same species cultivated at lower temperatures (18-10°C) (Reid and Horvath, 2000). Pasture Fe sampled during growing season showed marked seasonal fluctuations with peaks in spring and autumn, and Fe values can range from 70–111 to 2300–3850 mg/kg DM in New Zealand (Campbell *et al.*, 2002). This was in accordance with the findings by Halvorson and White (1983), who reported that Fe contents of western wheatgrass (*Agropyron smithii* Rydb.) and green needle grass (*Stipa viridula* Trin.) in the northern Great Plains decreased as the growing season progressed until maximum forage yield was reached in June. Iron then started to accumulate in these forages during the remainder of the growing season (Halvorson and White, 1983).

Changes in Zn concentration following plant maturity have been confirmed, but were not always consistent. In some studies, Zn concentration declined with increasing plant maturity in 24 different forages without any influence of the Zn status of the soil (Karn *et al.*, 2003). No such differences, however, were found in other studies comprising species like tall fescue and white clover (Reid *et al.*, 1967b; Gomide *et al.*, 1969; Whitehead and Jones, 1969).

CONCLUSION

The results show that the nutritive values of hyperrhenia were greatly affected as a result of seasonal variability. Crude protein carotene content of the grass was higher in the rainy season than in the cold and hot seasons, while mean dry matter and crude fibre content was higher in the hot dry season than in the rainy season. In terms of mineral content mean phosphorous, copper, iron and zinc content was higher in the rainy season than the cold and hot seasons. The remaining minerals such as calcium, magnesium and potassium where lower in the rainy season as compared to the cold and hot seasons.

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