Seasonal variation of mineral content in range grasses consumed by sheep

R.G. Ramírez[1]*, R. Morales-Rodríguez[1], G.J. García-Dessommes[2], H. González-Rodríguez[3],

*[*1]Facultad de Ciencias Biológicas, Universidad Autónoma de Nuevo León. Apartado Postal 142, Sucursal F, San Nicolás de los Garza, N.L., 66451, México.*
[2]Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias (INIFAP). General, Terán, N.L., México
[3]Facultad de Ciencias Forestales, Universidad Autónoma de Nuevo León, Km 12.5 Carr. Linares-Cd. Victoria, Linares, N.L., México.

*Correspondence author E-mail: roqramir@fcb.uanl.mx

Abstract

For grazing ruminants, native grasses are important sources of inorganic nutrients; however, in some circumstances, they are deficient in one or more essential minerals. The aim of this study was to compare, seasonally, during one year (from autumn 2001 to summer 2002), the Ca, K, Mg, Na, P, Cu, Fe, Mn, and Zn content of native gasses such as *Bouteloua curtipendula*, *Bouteloua trífida*, *Brachiaria fasciculata*, *Digitaria insularis*, *Chloris ciliata*, *Leptochloa filiformis*, *Panicum hallii*, *Panicum obtusum*, *Paspalum unispicatum*, *Setaria macrostachya*, *Setaria grisebachii*, *Tridens eragrostoides* and *Tridens muticus* and cultivated *Cenchrus ciliaris* and *Rhynchelytrum repens*. Grasses were collected by hand as encountered in four sites, randomly located, in a rangeland (900 ha) grazed by beef cattle at General Teran County, Nuevo Leon, México. Mineral concentrations were estimated using an atomic absorption spectrophotometer with an air/acetylene flame. The P content was determined in a colorimeter. All minerals, in all grasses, were significantly different between seasons and between grasses within seasons. In general, during wet seasons all grasses had higher mineral content. In all plants, in all seasons, K (overall mean = 12.0 g kg^{-1} DM), Mg (1.8), Fe (129.0 mg kg^{-1} DM), Mn (40.0) and Zn (49.0) were higher to meet growing beef cattle requirements; however, P (1.2), Na (0.3) and Cu (4) were lower. The Ca (5.0) was higher only in wet seasons (summer and autumn). Grazing cattle in these regions have to be supplemented with P, Na and Cu throughout the year and with Ca in dry seasons.

Introduction

Matching of livestock nutritional requirements with the optimum season for nutritional quality from the range grasses is an important element of livestock production systems. For example, grasses cure well, particularly in semiarid and arid climates, and stand as an excellent source of energy during their dormant season (Van Soest, 1994). *Rhynchelytrum repens* and *Cenchrus ciliaris* are cultivated species that were introduced to Mexico with good adaptation. Moreover, *Cenchrus ciliaris* because its wide distribution to these semiarid regions it has been considered as a naturalized grass. In addition, it has been mentioned as a south Texas and northeastern Mexico wonder grass (Hanselka, 1988); however, seasonality of rainfall and temperature are major influences on nutritional quality (Ramirez *et al*., 2003a).

Minerals are required to meet the animal needs for optimum development and health and influence animal productivity as they are essential nutrients and affect animal performance (McDowell, 2003). Range grasses may be important sources of inorganic nutrients for ruminants; however, in some circumstances, they are deficient in one or more essential minerals. The aim of this study was to determine and compare seasonally the Ca, P, Na, Mg, K, Cu, Mn, Fe and Zn content in the forage of two cultivated and thirteen native grasses growing in northeastern Mexico.

Materials and Methods

The study was carried out at the “Sauces Ranch” of about 900 ha located in General Terán County of the state of Nuevo León, México. It is located at 25°24´26´´ west longitude and 99°46´33´´ north latitude, with an altitude of 272 m. The climate is typically subtropical and semi-arid with a warm summer. Mean monthly air temperature ranges from 14.7°C in January to 22.3°C in August, although daily high temperatures of 45°C are common during the summer. Peak rainfall months are May, June and September. Annual rainfall during the year of study was about 360 mm distributed as follows; 25 mm in winter, 32 mm in spring, 238 mm in summer and 65 mm in autumn. The main type of vegetation is known as the Tamaulipan Thornscrub or Subtropical Thornscrub Woodlands (SPP–INEGI, 1986). The dominant soils are deep, dark-gray, lime-gray, lime-clay Vertisoles, with montmorillonite, which shrink and swell noticeably in response to changes in soil moisture content. They are characterized by high clay and calcium carbonate contents, pH varied from 7.5 to 8.5 and low organic matter content (Foroughbakhch, 1992).

Grasses such as *Bouteloua curtipendula* (Gould & Kapadia), *Bouteloua trífida* (Thurber), *Brachiaria fasciculata* (Sw.), *Digitaria insularis* (L.), *Chloris ciliata* (Swartz.), *Leptochloa filiformis* (Lam.) Beauv, *Panicum hallii* (Vasey.), *Panicum obtusum* (H.B.K.), Parodi., *Paspalum unispicatum* (L.), *Setaria macrostachya* (H.B.K.), *Setaria grisebachii* (Fourn.), *Tridens eragrostoides* (Vasey & Scribn.) Nash, *Tridens muticus* (Torr.) Wash. And the cultivated *Cenchrus ciliaris* (L.) and *Rhynchelytrum repens* (Willd.) Hubb, were collected for nutritional studies because they represent and important source of forage for grazing ruminants in northeastern Mexico (Ramírez *et al*., 1999). In this study, *C. ciliaris* has been considered as reference grass of good nutritional quality. Collection of grasses was made during the four seasons beginning in autumn of 2001 (October 20), followed by winter of 2002 (January 21), spring of 2002 (April 28) and summer of 2002 (July 23). As encountered in four sites, randomly located in all ranch, grasses were hand harvested until adequate amounts of material were obtained, and compositing by species in each site and in each season. Samples were stored in paper bags in the field and transported to laboratory. The sites of collection were grazed by livestock. Partial dry matter was determined subjecting samples to oven at 55° C during 72 h, then were ground in a Wiley mill (1 mm) and stored in plastic containers for further analyses.

In each season, by quadruplicate, samples were analyzed for DM and ash content (AOAC, 19). Mineral content was estimated by incinerating the samples in a muffle at 550°C, during 5 hours. Ashes were digest ed in a solution containing HCl y HNO_3, using the wet digestion technique (Diaz-Romeau and Hunter, 1978). Concentrations of Ca, Mg, K, Na, Fe, Mn, Zn and Cu were estimated using an atomic absorption spectrophotometer. The P content was estimated in a colorimeter (AOAC, 1997).

Data were statistically analyzed using an experimental design of two ways of classification (being grasses and seasons the study factors), with interaction between seasons and grasses. The interaction seasons x grasses was significant ($P<0.05$), thus analyses of variance were carried out among seasons and among grasses within seasons (Steel and Torrie, 1980).

Results and discussion

Ash content in all grasses was significantly different among seasons and among grasses within seasons. *Brachiaria fasciculata* was higher and *T. muticus* was lower. Most of the native grasses resulted with higher mineral content than cultivated grasses (Table 1). Calcium content in all grasses was significantly different among seasons and all grasses within seasons. *Chloris ciliata, P. obtusum* and *P. unispicatum* had higher Ca content (annual mean) and *B. curtipendula, D. insularis, S. macrostachya* and *T. eragrostoides* were lower (Table 1). Growing beef cattle requires in its diet 4.5 g of Ca kg^{-1} DM (McDowell, 2003). It seems that most of the grasses during dry seasons (winter and spring) had insufficient Ca to meet requirements. It appears that P requirements of growing beef cattle are of 3.0 g kg^{-1} in the DM of its diet. In this study, none of the grasses had sufficient P to meet requirements. Martin-Rivera and Ibarra-Flores (1989) also found low Ca and P in native grasses from northern of Mexico such as *Aristida* spp. (in spring 2.2 and 1.0; in summer 1.8 and 2.1; in autumn 2.3 and 0.8 and in winter 2.5 and 1.4 g kg^{-1} DM,), *S. macrostachya* (3.4 and 1.0, 2.6 and 2.1, 3.6 and 2.1, 2.4 and 0.5, respectively) and *B. gracilis* (2.8 and 1.2, 3.9 and 2.2, 5.5 and 1.9, 2.1 and 0.7, respectively). Moreover, Dittberner and Olson (1983) reported lower Ca and P content in *B. gracilis* (2.8 and 0.7 g/kg DM, respectively in aerial part fresh immature and 4.0 and 1.6 in aerial part fresh dormant). Huston *et al*. (1981) also found lower values of Ca and P (1.4 and 1.0 g/kg DM in early summer in late summer) in *P. hallii* collected in Texas, U.S. Recently, Ramirez *et al*. (2004) also found low P content in native grasses such as *P. hallii* (1.2 g kg^{-1} DM), *Bouteloua gracilis* (0.8), *S. macrostachya* (1.0), *Hilaria berlangeri* (0.7), *Cenchrus incertus* (1.4) and *Aristida longiseta* (0.5). However, Ganskopp y Bohnert (2003) who evaluated the P content in native grasses growing in north Texas, US found that average concentration was 1.94 g kg^{-1} DM which is an inadequate level to meet growing cattle needs.

With exception of *C. ciliaris*, *C. ciliata* and *T. eragrostoides*, all grasses had Mg content significantly different among seasons and all grasses were also significant different within seasons. With exception of *B. curtipendula* and *B. trifida* all grasses in most seasons had marginal sufficient levels to meet the needs (1.0 g kg^{-1} DM; McDowell, 2003) of growing beef cattle. *Paspalum unispicatum* resulted with higher Mg content and *B. curtipendula* and *B. trifida* were lower (Table 1). Similar results to this study were reported by González and Everitt (1982) who evaluated the Mg content of native grasses of the generous *Bouteloua, Brachiaria, Chloris* y *Paspalum* growing in south Texas, US. Moreover, Pinchak *et al*. (1989) also found that several native grasses from south Texas had enough Mg concentration to fulfill the Mg needs of growing cattle. Ramírez *et al*. (2004) also found that native grasses such as *Aristida longiseta, P. hallii, Cenchrus incertus, B, gracilis* and *Hilaria berlangeri* collected in northeastern Mexico had Mg concentrations in sufficient amounts to meet growing beef cattle requirements. Ganskopp y Bohnert (2003) reported that Mg content in native grasses from north Texas followed a seasonal pattern. They found that Mg concentration increased as seasons progressed, and all grasses in all seasons had sufficient Mg to meet growing beef cattle needs. Conversely, Kalmbacher (1983) reported that four native grasses from Florida, US had insufficient amounts of Mg, in all seasons, to meet the needs of cattle. In this study, high levels of K may cause Mg deficiency because Mg is absorbed from the rumen by two active processes (Dua and Care, 1995) against an electrochemical gradient; the process is inhibited by K (Care *et al*., 1984)

The K content in all grasses was significantly different among seasons and in all grasses within seasons (Table 2). With exception of *B. curtipendula*, *B, trifida* and *T. muticus*, all grasses had sufficient K to meet requirements of growing beef cattle (6.0 g kg^{-1} DM; McDowell, 2003). Native grasses with adequate levels of K for growing beef cattle needs are also found in several species growing in south (González y Everitt, 1982; Pinchak, *et al*. (1989) and north (Ganskopp y Bohnert (2003) Texas, US, northeastern Mexico (Ramirez *et al*., 2004) and Florida, US (Kalmbacher, 1983).

The Na concentration in all grasses was significantly different among seasons and among grasses within seasons (Table 2). Growing beef cattle requires 0.6 g kg^{-1} DM in their diets (McDowell, 2003). In this study, in all seasons, all grasses had insufficient amounts of Na to meet requirements. It appears that all grasses can be considered as Na non-accumulators because they contain less that 2 g Na kg^{-1} DM (Youssef, 1988). High K content in evaluated grasses (Table 4) could reduce Na absorption of cattle feeding these grasses because it has been reported that elevated dietary K may decrease ruminal concentration and absorption of Na in steers (Spears, 1994). However, sodium deficiencies can be alleviated by supplementing common salt.

With exception of *B. curtipendula and T. muticus* Cu content, in all grasses was significantly different among grasses and among all grasses within seasons (Table 2). It seems that all grasses, in all seasons, had insufficient Cu to meet growing beef cattle requirements (10 mg kg^{-1}; McDowell, 2003). Low Cu concentrations are also reported in native grasses growing in semiarid regions (Barnes *et al*., 1990; Ramirez *et al*., 2004). Low Cu in evaluated grasses may be caused because the high pH (7.5-8.5) in soils (Spears, 1994) of these regions. The Fe content among grasses was significantly different and among all grasses within seasons. *Panicum obtusum* was higher and *B. curtipendula* was lower. During summer and autumn most grasses had higher ($P<0.001$) Fe content (Table 2). Growing beef cattle requires 50 g kg^{-1} of Fe in the DM of the diet (McDowell, 2003). In this study, all grasses, in all seasons had Fe in amounts to meet requirements. Similar findings were reported by Ramirez *et al*. (2004). They sustained that range grasses had Fe levels in substantial amounts to meet requirements. Ganskopp and Bohnert (2003) who evaluated Fe content in native grasses growing in north Texas, US, found levels (>48.0 mg kg^{-1}) that also exceeded requirements. In addition, Kalmbacher (1983) reported that native grasses from Florida, USa, had sufficient Fe for pregnant beef cattle requirements. Iron deficiency seldom occurs in grazing ruminants due to generally adequate pasture concentrations and contaminants of plants by soil. Soil contamination of forages and direct soil consumption often provide excess quantities of dietary Fe (McDowell, 2003)

The Mn content was significant different among grasses and among all grasses within seasons (Table 3). *Chloris ciliata* resulted with higher Mn content and *L. filiformis* was lower. Even though Mn content was lower (P<0.001) during the dry seasons (winter and spring), all grasses had sufficient amounts to meet the requirements of growing beef cattle (20 g kg^{-1} of DM; McDowell, 2003). Although Mn deficiency has been produced experimentally in ruminants, with effects on skeletal development and reproductive performance, doubt has been expressed whether this deficiency arises under field conditions. However, contrary to our findings, Mn deficiency for ruminants under grazing conditions has been reported in United States and other countries (McDowell, 1985). The Zn content was significantly different among seasons and among all grasses within seasons. *Paspalum unispicatum* was higher and *B. trifida* had lower (Table 3). During summer and autumn the Zn content in most grasses was higher (P<0.001). With exception of *B. trifida*, in all seasons, all grasses had Zn content to meets requirements of growing beef cattle (30 g kg^{-1} DM; McDowell, 2003). Similar findings were reported by Ramirez *et al*. (2004) who evaluated the Zn content of seven native grasses growing in northeastern Mexico. However, Ganskopp and Bohnert (2003) found that the amount of Zn (mean = 28 g kg^{-1} DM) in native grasses growing in north Texas, USA, was insufficient to satisfy growing cattle requirements. A high level of Ca increases the dietary Zn requirements, so that supplemental Zn is required to prevent parakeratosis in cattle when the diet is high of Ca. However, in this study the Ca levels, especially during dry seasons, were lower, thus Zn deficiency may not occur.

Conclusions

Growing beef cattle grazing on these grasses could not require supplementary Mg, K, Fe, Mn and Zn but they must require P, Na and Cu supplementation throughout the year, whereas, Ca would be complementary when seasonal rainfall is sparse.

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Table 1
Seasonal and annual means of Ashes, Ca, P and Mg in cultivated grasses *Cenchrus ciliaris,* and *Rhynchelytrum repens* and thirteen native grasses growing in northeastern Mexico

Grasses	Ashes[x]							Ca[x]						
	Seasons[y]							Seasons						
	w	sp	su	f	M	SEM	Sig	w	sp	su	f	M	SEM	Sig
B. curtipendula	11	11	9	8	10	0.1	***	4	4	5	3	4	0.3	***
B. trifida	10	7	7	8	8	0.1	***	3	5	7	5	5	0.2	***
B. fasciculata	14	15	12	17	15	0.1	***	7	8	6	7	7	0.1	***
C. ciliaris	8	8	9	9	8	0.3	*	6	4	5	7	6	0.1	***
C. ciliata	11	10	9	10	10	0.05	***	9	7	6	7	7	0.2	***
D. insularis	10	9	8	11	10	0.1	***	3	4	4	4	4	0.2	***
L. filiformis	14	13	12	12	13	0.3	*	5	5	4	6	5	0.5	***
P. hallii	10	9	9	11	10	0.06	***	6	7	6	5	6	0.3	***
P. obtusum	14	15	11	13	13	0.4	*	9	9	5	7	7	0.3	***
P. unispicatum	14	14	11	15	14	0.05	***	7	5	8	6	7	0.3	***
R. repens	10	9	7	6	8	0.06	***	6	8	6	6	6	0.2	***
S. grisebachii	16	11	12	15	14	0.4	**	4	4	4	5	5	0.2	***
S. macrostachya	13	10	15	14	13	0.03	***	3	4	5	3	4	0.3	***
T. eragrostoides	8	8	8	9	8	0.06	***	4	4	5	5	4	0.3	***
T. muticus	7	8	8	7	7	0.03	***	5	5	5	5	5	0.1	***
Seasonal means	11	10	10	11	11			6	5	5	5			
SEM	0.2	0.2	0.1	0.2				0.1	0.7	0.1	0.1			
Significant level	***	***	***	***				***	***	***	***			
Requirement[z]											4.5 g kg-1			

Table 1 Continued.-

Grasses	P[x]							Mg[x]						
B. curtipendula	0.8	1.3	0.6	0.9	0.9	0.1	**	0.7	0.9	0.7	0.7	0.8	0.1	*
B. trifida	0.7	1.0	0.8	0.4	0.7	0.02	***	0.6	0.9	1.0	0.8	0.8	0.02	***
B. fasciculata	0.9	1.2	1.5	1.4	1.3	0.02	*	2.2	1.1	3.1	3.7	2.5	0.03	***
C. ciliaris	1.1	1.2	1.5	1.1	1.2	0.1	*	1.1	1.8	1.2	1.9	1.5	0.30	NS
C. ciliata	1.1	1.2	1.5	1.4	1.3	0.03	**	1.8	1.8	1.8	1.9	1.8	0.1	NS
D. insularis	1.0	1.4	1.0	1.1	1.1	0.04	**	0.7	2.1	1.1	1.1	1.2	0.04	***
L. filiformis	1.2	1.0	1.8	1.8	1.5	0.03	***	1.6	0.8	1.6	2.1	1.5	0.1	***
P. hallii	1.1	0.6	1.2	1.3	1.1	0.1	***	1.3	0.7	2.8	3.2	2.0	0.1	***
P. obtusum	1.4	1.1	1.4	1.7	1.4	0.1	*	2.1	1.5	1.6	1.6	1.7	0.1	***
P. unispicatum	0.9	1.6	1.7	1.3	1.4	0.02	**	1.5	2.5	3.4	2.0	2.6	0.04	***
R. repens	0.8	0.6	0.9	0.8	0.8	0.02	*	2.0	2.0	3.0	2.0	1.8	0.1	***
S. grisebachii	0.9	1.1	1.3	1.7	1.3	0.1	***	2.0	1.1	2.0	2.5	2.0	0.1	***
S. macrostachya	1.5	1.1	1.5	1.7	1.5	0.1	***	1.2	1.2	2.8	1.3	1.6	0.1	***
T. eragrostoides	1.1	1.3	1.0	1.1	1.1	0.05	*	1.3	1.2	1.2	1.3	1.3	0.04	NS
T. muticus	0.5	1.3	0.6	0.4	0.7	0.01	***	0.7	2.2	1.3	1.0	1.3	0.02	***
Seasonal means	1.0	1.1	1.2	1.2	1.1			1.4	1.5	1.9	1.8			
SEM	0.02	0.01	0.01	0.02				0.02	0.03	0.03	0.1			
Significant level	***	***	***	***				***	***	***	***			
Requirement[z]				3.0 g kg^{-1}							1.0 g kg-1			

[x]g/kg DM; [z]w = winter; sp= spring; su = summer; f = fall; SEM = standard error of the mean; Sig = significancy *(P<0.05); **(P<0.01); ***(P<0.001); NS = no significant.
[z]Required by growing beef cattle (McDowell, 2003)..

Table 2
Seasonal and annual means of K, Na, Cu, and Fe in cultivated grasses *Cenchrus ciliaris,* and *Rhynchelytrum repens* and thirteen native grasses growing in northeastern Mexico

Grasses	K^x							Na^x						
	Seasons[y]							Seasons						
	w	sp	su	f	M	SEM	Sig	w	sp	su	f	M	SEM	Sig
B. curtipendula	3	7	6	4	5	0.8	***	0.1	0.1	0.2	0.2	0.2	0.1	**
B. trifida	2	4	4	2	3	0.1	***	0.2	0.1	0.2	0.2	0.2	0.04	*
B. fasciculata	6	2	33	18	15	0.4	***	0.1	0.2	0.4	0.2	0.2	0.1	***
C. ciliaris	16	29	16	24	21	0.3	***	0.6	1.0	0.7	1.4	0.9	0.1	***
C. ciliata	10	7	21	15	13	0.7	***	0.4	0.2	0.5	0.4	0.4	0.1	***
D. insularis	7	16	19	9	13	0.3	***	0.2	0.2	0.2	0.2	0.2	0.1	NS
L. filiformis	4	1	10	9	6	0.5	***	0.1	0.1	0.3	0.3	0.2	0.1	***
P. hallii	5	2	19	13	10	0.6	***	0.1	0.3	0.3	0.2	0.2	0.1	NS
P. obtusum	13	11	27	17	17	0.7	***	0.3	0.1	0.2	0.3	0.2	0.1	NS
P. unispicatum	7	21	16	13	14	0.3	***	0.2	0.4	0.2	0.2	0.3	0.2	NS
R. repens	7	7	12	8	9	0.7	***	0.1	0.2	0.1	0.2	0.2	0.1	NS
S. grisebachii	8	7	33	19	17	0.8	***	0.1	0.2	0.2	0.1	0.2	0.1	NS
S. macrostachya	19	11	40	29	25	2.8	***	0.3	0.2	1.1	0.4	0.5	0.04	***
T. eragrostoides	14	19	11	13	14	1.3	***	0.2	0.1	0.2	0.3	0.2	0.03	***
T. muticus	2	6	7	4	5	0.3	***	0.2	0.1	0.1	0.2	0.2	0.03	***
Seasonal means	8	10	18	13	12			0.2	0.2	0.3	0.3	0.3		
SEM	0.4	0.4	0.3	0.4				0.01	0.02	0.02	0.01			
Significant level	***	***	***	***				***	***	***	***			
Requirement[z]	6.0 g kg-1							0.8 g kg-1						

Table 2 Continued.-

	Cu^z							Fe^z						
B. curtipendula	2	2	1	2	2	0.3	NS	56	66	92	84	74	6.0	***
B. trifida	3	2	2	2	2	0.2	**	79	78	189	75	105	20.1	***
B. fasciculata	3	4	8	2	4	0.2	***	100	128	153	175	139	5.8	***
C. ciliaris	5	10	8	9	8	0.2	***	114	164	120	176	144	8.1	***
C. ciliata	3	3	6	4	4	0.2	***	119	198	150	165	158	10.4	***
D. insularis	2	6	3	2	3	0.3	***	58	108	143	191	125	12.5	***
L. filiformis	6	5	2	3	4	0.4	***	118	120	126	124	122	18.4	***
P. hallii	3	2	6	3	3	0.2	***	188	126	188	180	170	5.7	***
P. obtusum	6	5	3	4	5	0.3	***	188	176	188	181	183	8.5	***
P. unispicatum	4	6	4	4	4	0.2	***	116	135	152	185	147	6.0	***
R. repens	3	4	6	4	4	0.2	***	53	77	135	97	91	5.5	***
S. grisebachii	2	3	7	3	4	0.2	***	104	90	147	122	116	7.8	***
S. macrostachya	2	3	8	3	4	0.5	***	91	75	155	99	105	11.4	***
T. eragrostoides	4	5	3	3	4	0.4	***	148	108	173	110	135	13.9	***
T. muticus	2	2	2	2	2	0.1	NS	117	96	137	113	115	4.6	***
Seasonal means	3	4	5	3	4			110	116	150	138	129		
SEM	0.1	0.1	0.1	0.1				4.7	6	6	4			
Significant level	***	***	***	***				***	***	***	***			
Requirement[z]	10 mg kg^{-1}							50 mg kg^{-1}						

[x]g/kg DM; [y]mg/kg DM; [z]w = winter; sp= spring; su = summer; f = fall; SEM = standard error of the mean; Sig = significancy *(P<0.05); **(P<0.01); ***(P<0.001); NS = no significant.
[z]Required by growing beef cattle (McDowell, 2003).

Table 3
Seasonal and annual means of Mn and Zn in cultivated grasses *Cenchrus ciliaris,* and *Rhynchelytrum repens* and thirteen native grasses growing in northeastern Mexico

Grasses	Mn[x]							Zn[x]						
	Seasons[y]							Seasons						
	w	sp	su	f	M	SEM	Sig	w	sp	su	f	M	SEM	Sig
B. curtipendula	46	40	49	47	45	1.2	***	31	45	64	50	48	4.5	***
B. trifida	38	30	38	36	36	0.8	***	15	25	29	27	24	3.8	***
B. fasciculata	54	31	78	89	63	2.0	***	46	45	64	55	52	3.1	***
C. ciliaris	27	44	33	39	36	1.4	***	41	52	43	71	52	1.5	***
C. ciliata	70	67	80	76	88	2.8	***	31	51	46	45	43	1.3	***
D. insularis	28	27	23	33	27	1.4	***	61	47	74	60	60	2.8	***
L. filiformis	25	24	29	22	25	1.9	***	49	43	62	61	53	3.8	***
P. hallii	46	38	45	45	43	1.0	***	29	29	58	29	37	2.3	***
P. obtusum	34	32	34	38	35	0.8	***	32	44	58	52	46	3.4	***
P. unispicatum	25	46	48	42	40	0.7	***	66	53	82	76	69	2.1	***
R. repens	30	24	29	27	28	1.5	***	50	51	39	43	46	2.7	***
S. grisebachii	31	29	35	30	31	1.2	***	55	57	69	59	60	5.4	***
S. macrostachya	31	36	40	33	35	1.5	***	59	59	57	43	55	5.6	NS
T. eragrostoides	38	31	44	40	38	2.1	***	50	64	66	53	58	4.4	***
T. muticus	22	29	30	28	27	0.6	***	29	38	31	37	34	1.4	***
Seasonal means	36	35	42	42	40			43	47	56	51	49		
SEM	0.8	1.7	0.8	0.8				1.3	0.8	0.4	1.0			
Significant level	***	***	***	***				***	***	***	***			
Requirement[z]				20 mg kg^{-1}							30 mg kg^{-1}			

[x]mg/kg DM; [y]w = winter; sp= spring; su = summer; f = fall; SEM = standard error of the mean; Sig = significancy *(P<0.05); **(P<0.01); ***(P<0.001); NS = no significant.
[z]Required by growing beef cattle (McDowell, 2003).