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Macro Mineral Content in Five Shrubs Browsed by White-Tailed Deer (*Odocoileus virginianus*), Northeastern Mexico

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Abstract: The Ca, K, Mg, Na and P contents were determined, seasonally during 2 consecutive years in leaves of native browse plants such as *Castela erecta* Turp sp. Texana (Torr & A. Gray) Cronquist (Simaroubaceae), *Celtis pallida* Torr. (Ulmaceae), *Forestiera angustifolia* Torr. (Oleaceae), *Lantana macropoda* Torr. (Verbenaceae) and *Zanthoxylum fagara* (L.) Sarg (Rutaceae) that were collected from August 2004 to May 2006 in a semiarid and subtropical area of the State of Nuevo Leon, Mexico at three county (Los Ramones, China and Linares) sites which are grouped under a similar climatic pattern. Mineral contents were measured using an atomic absorption spectrophotometer with exception of P content that was estimated using a colorimeter. All minerals in all species were significantly different among years, sites and seasons and interactions were also significant. In general, plants at Linares site which historically registered the highest rainfall had higher mineral content followed by Los Ramones and China. Moreover, during the 2nd year, all plants species showed higher mineral content than the 1st year. Furthermore, during the Summer session, all plants species had higher mineral content followed by Autumn, Winter and Spring. Regardless of spatio-temporal differences, all plant species had suitable levels of Ca, Mg and K to satisfy range domestic and wild ruminant requirements. In contrast, P and Na contents showed marginal inadequacies in some seasons throughout the year. Seasonal variations in minerals could be associated to climatic conditions like excessive irradiance levels during Summer and extreme low temperatures in Winter and rainfall events.

Key words: Nutrition, Tamaulipan thornscrub, wild ruminants, minerals, native forages

INTRODUCTION

The Tamaulipan Thornscrub or Subtropical Thornscrub is located at Northeastern Mexico in the physiographical province known as the Coastal Gulf plain. It begins in the Eastern part of the Coahuila State in Mexico at the base of the Sierra Madre Oriental and then proceeds eastward to encompass the Northern half of the state of Tamaulipas and into the United States through the South Western side of Texas. Elevation increases Northwesterly from sea level near the Gulf Coast to a base of about 300 m near the Northern boundary of the eco-region from which a few hills or mountains protrude (Everitt *et al*., 2002).

Range livestock and white-tailed deer need macro minerals for skeletal growth, milk production and the maintenance of body fluids mainly (Fulbright and Ortega, 2006; Whitehead, 2000). The concentration of minerals in plants is dependent upon interactions among a number of factors including soil type, plant species, stage of maturity, dry matter yield, grazing management and climate (McDowell, 2003). Besides it has documented that environmental factors such as temperature and rainfall, influenced on mineral content in shrubs (Ramirez *et al*., 2010). Although, the concentration of a mineral in the forage is important, the biological availability of the mineral is equally important. Biological availability (absorption and utilization) of minerals varies substantially among animal species and breeds within a

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species as well as among forages. The combination of all of these factors makes it extremely difficult for range nutritionists to determine mineral status of the range ruminant animal (Underwood and Shuttle, 1999).

The aims of this study were to determine and compare, seasonally, throughout 2 consecutive years, Ca, K, Mg, Na and P contents of five native plants that are consumed by white-tailed deer. Objectives were developed from the hypothesis that browse plants, growing in Northeastern Mexico, contain essential minerals in sufficient amounts to meet the nutritional requirements of white-tailed deer.

MATERIALS AND METHODS

This study was carried out at three sampling sites situated in the state of Nuevo Leon, Northeastern Mexico. The first site was located at El Abuelo ranch in Los Ramones county (25°40'N; 99°27'W) with an elevation of 200 m. The second site was located at the campus of the Facultad de Ciencias Forestales, Universidad Autonoma de Nuevo Leon (24°47'N; 99°32'W; elevation of 350 m) located at Linares county. The third site was located at Zaragoza ranch in China county (25°31'N; 99°16'W). It has an elevation also of 200 m. Vegetation of the three sites is composed by browse plants that are consumed by range livestock (cattle, sheep and goats) and wildlife (white-tailed deer) and is representative of the central region of the state of Nuevo Leon.

The main native vegetation type covering much of the Northeastern region of Mexico and parts of Southern Texas is mesquite-grassland, an important element of the ecoregion that plant ecologists classify as characteristic of the Tamaulipan biotic province. The Tamaulipan province extends South of the border for almost 362 km between the coast and the deciduous woodlands on the slopes of the Sierra Madre Oriental. The Tamaulipan thornscrub, a subtropical, semi-arid vegetation type, occurs on either side of the Rio Grande, Texas, USA and Northeastern Mexico. Spiny shrubs and trees dominate this thornscrub but grasses, forbs and succulents are also prominent. This region also includes elements of the range, a combination of grassland, savanna and paramo-like communities. Leguminous shrubs and trees constitute one-third of the diverse woody flora which the rural population uses for extensive grazing of livestock, fuel wood and timber for fencing and construction (Everitt *et al.*, 2002).

In general, the three sites used in this study are grouped under a similar climatic pattern (subtropical and semiarid with warm Summer) with an annual precipitation that ranges from 650-800 mm with a bimodal distribution (peaks rainfall are during May, June and August, September). Monthly mean air temperature of the region ranges from 14.7°C in January to 22.3°C in August, although daily high temperatures of 45°C are common during Summer (Gonzalez-Rodriguez *et al.*, 2004). Los Ramones and China sites have not registered livestock activities in the last 5 years and Linares since, the last 25 years. In this study, seasonal rainfall and mean air temperature registered at each site are shown in Table 1. The main type of vegetation of the area is known as the Tamaulipan Thornscrub or Subtropical Thornscrub Woodlands. Dominant soils are deep, dark-gray, lime-gray and lime-clay Vertisols with montmorillonite which shrink and swell noticeably in response to changes in soil moisture content.

Plant species such as *Castela erecta* Turp sp. Texana (Torr & A. Gray) Cronquist (Simaroubaceae), *Celtis pallida* Torr. (Ulmaceae), *Forestiera angustifolia* Torr. (Oleaceae), *Lantana macropoda* Torr. (Verbenaceae) and *Zanthoxylum fagara* (L.) Sarg (Rutaceae) are representative of the native vegetation of the Northeastern Mexico and the subtropical savanna ecosystems of Southern Texas, USA (Everitt *et al.*, 2002) and are consumed by white-tailed deer. Terminal shoots with fully expanded leaves were randomly chosen from a 50×50 m representative and

Table 1: Environmental conditions registered from Summer 2004 to Spring 2006 at research sites, Northeastern Mexico

		Site					
		Los Ramones		Linares		China	
Seasons	Years	T (°C)	Rainfall (mm)	T (°C)	Rainfall (mm)	T (°C)	Rainfall (mm)
Summer 2004	1	22.8	29.4	23.6	447	23.6	457
Autumn 2004		17.7	96.0	22.1	95	19.4	31
Winterr 2005		10.1	98.0	13.4	133	11.3	74
Spring 2005		16.5	96.0	20.5	94	18.2	140
Total rainfall			319.4		769		702
Summer 2005	2	23.1	322.0	23.4	465	24.5	486
Autumn 2005		17.2	194.0	19.0	316	19.5	101
Winterr 2006		8.7	4.0	9.7	9	11.5	14
Spring 2006		18.8	158.0	19.6	79	19.9	150
Total rainfall			1316.8		2407		2155

undisturbed Thornscrub plot located in each site. Collections were undertaken, seasonally during 2 consecutive years: Summer 2004 (August 28), fall 2004 (November 28), Winterr 2005 (February 28), Spring 2005 (May 28), Summer 2005 (August 28), fall 2005 (November 28), Winterr 2006 (February 28) and spring 2006 (May 28). Shoots were excised and sampled (about 800 g) from the middle side of four plants (replications) of each species. Leaves were placed into paper bags and stored then samples were transferred to laboratory for mineral analyses.

Quadruplicate samples of each plant species were used for analyses. Partial Dry Matter (DM) was determined subjecting samples to an oven and dried at 55°C for 72 h. Then, samples were ground in a Wiley mill (1 mm) and stored in plastic containers for further analyses. Mineral content was estimated by incinerating samples in a muffle oven at 550°C during 5 h. Ashes were digested in a solution containing HCl and HNO_3 using the wet digestion technique (Cherney, 2000). Contents of Ca and Mg (oxide nitrous/acetylene flame), K, Na were determined by atomic absorption spectrophotometry using a Varian Spectrophotometer (Model SpectrAA-2000) whereas P was quantified spectrophotometrically using a Perkin-Elmer spectrophotometer (Model Lamda 1A; Perkin-Elmer Corp., Analytical Instruments, Norwalk, CT, USA) (AOAC, 2000). Mineral data were statistically analyzed using one-way analysis of variance with a multi-factorial arrangement being years (2), sites (3), seasons (4) and plant species (5) the factors. All applied statistical methods were computed using the SPSS Package (Version 9).

RESULTS AND DISCUSSION

All browse species had Ca, P, Mg, K and Na contents that were significantly different among sites, years and seasons. The interactions: site x year, site x season, year x season and site x year x season were also significant ($p<0.001$). In general, in Linares site that showed the highest rainfall (Table 1) and the highest macromineral content. Except for *C. erecta*, all shrub species during 2nd year and Summer season had the highest values. Moreover, China site during the 2nd year and during Winterr season had the lowest values.

The Ca content was higher in *L. macropoda* (total mean = 37.3 g kg^{-1} DM) and *C. erecta* (24.3 g kg^{-1} DM) was lower (Table 2). During the wet seasons (Summer and

Table 2: Seasonal means of Ca content (g kg^{-1} DM) in native plants from Northeastern Mexico

Sites	Seasons	*C. erecta*	*C. pallida*	*F. angustifolia*	*L. macropoda*	*Z. fagara*
Los Ramones	Summer 2004	26.5	52.4	25.2	38.5	27.9
	Autum 2004	30.8	50.6	24.2	36.4	25.6
	Winterr 2005	29.5	48.4	22.5	34.2	24.2
	Spring 2005	24.7	46.4	20.6	31.6	20.2
	Summer 2005	24.9	54.6	26.6	39.2	29.7
	Autum 2005	16.1	52.4	24.2	37.2	28.2
	Winterr 2006	21.4	49.6	22.4	35.6	25.6
	Spring 2006	22.4	38.2	21.2	32.1	21.0
Linares	Summer 2004	25.7	58.3	28.6	41.1	36.2
	Autum 2004	22.9	56.4	26.4	39.6	32.3
	Winterr 2005	22.3	54.2	24.2	38.4	28.5
	Spring 2005	28.7	50.3	23.6	36.5	27.2
	Summer 2005	25.7	63.2	29.2	43.2	38.6
	Autum 2005	23.2	60.1	27.6	40.6	32.4
	Winterr 2006	24.9	57.6	25.6	39.4	29.5
	Spring 2006	22.4	55.4	24.1	37.1	26.5
China	Summer 2004	20.4	54.2	26.2	40.2	30.2
	Autum 2004	29.4	52.6	25.1	37.2	27.5
	Winterr 2005	22.0	49.4	23.2	35.4	25.6
	Spring 2005	22.8	37.6	21.4	32.1	24.2
	Summer 2005	31.8	55.6	27.2	41.4	31.2
	Autum 2005	25.5	53.2	25.6	38.6	28.6
	Winter 2006	17.1	51.3	23.1	36.5	27.2
	Spring 2006	22.8	20.4	22.2	34.2	25.6
	Grand Mean	24.3	50.9	24.6	37.3	28.1
	SEM	1.0	0.6	0.1	0.2	0.3
	Effects	p	p	p	p	p
	Year (A)	<0.001	<0.001	0.01	<0.001	<0.001
	Site (B)	<0.001	<0.001	<0.001	<0.001	<0.001
	Season (C)	<0.001	<0.001	<0.001	<0.001	<0.001
	A×B	0.7	0.05	0.9	0.63	0.7
	A×C	<0.001	<0.001	<0.001	<0.001	0.001
	B×C	<0.001	<0.001	0.93	<0.001	<0.001
	A×B×C	<0.001	<0.001	0.01	<0.001	0.01

SEM = Standard Error of the Mean; n = 4; p = probability mineral content was higher compared to dry seasons. Rainfall (r = 0.65; $p<0.001$) and temperature (r = 0.69; $p<0.001$) registered during the 2 years study were positively correlated to Ca content in all plants. Seasonal inter species variation that occurred in this study was also reported by Greene *et al.* (1987). In this study, in spite of spatio-temporal differences it appears that evaluated plants had substantial amounts of Ca, throughout the year, to sustain requirements of adult range white-tailed deer (4.5 g kg^{-1} of diet DM; NRC, 2007). In addition, Thomas *et al.* (1990) in South Texas, USA and Ramirez *et al.* (2001), Cerrillo-Soto *et al.* (2004), Ramirez-Orduna *et al.* (2005), Ramirez *et al.* (2006), Haenlein and Ramirez (2007), Guerrero-Cervantes (2009) and Ramirez *et al.* (2010) in North Mexico, reported that native shrubs and trees growing in semiarid and tropical regions had enough Ca for optimal white-tailed deer performance. High pH in the soils of these regions may be the cause why shrubs are high in Ca content (Spears, 1994). Most plants in this study had Ca content above 16 g kg^{-1} DM. Meeting Ca requirements is seldom a problem under grazing or browsing conditions with free-ranging white tailed deer (Whitehead, 2000).

All species had P content that varied from 1.6-2.1 g kg^{-1} DM (Table 3). Similar ranges were reported by Thomas *et al.* (1990) (1.5-2.8), Ramirez *et al.* (2001) (1.4-2.6) and Moya-Rodriguez (1.5-2.2). However, a higher range (2.0-4.0 kg^{-1}) was documented by Guerrero-Cervantes (2009) in native shrubs growing in North Mexico. In this study, most plants, in all sites, years and seasons had P contents that were not sufficient to meet adult white-tailed deer (2.8 g kg^{-1} DM; NRC, 2007), especially during dry seasons (Winterr and spring). The rainfall (r = 0.65; $p<0.001$) and temperature (r = 0.68; $p<0.001$) registered during the 2 years study were positively and significantly related to P content in all plants. During the wet seasons, of both years with higher temperatures (Summer and Autumn), the mineral content was higher compared to dry seasons. Low P and high Ca contents resulted in an unusually wide Ca:P ratio (from 9:1-22:1). Similarly, a wide range in Ca:P ratio have been reported by Kallah *et al.* (2000). However, it seems that the browsing of small ruminants (goats, sheep and white-tailed deer) can sustain these high Ca:P ratios without being affect their P metabolism (Ramirez, 1999).

The Mg content (Table 4) was higher in *C. pallida* (total mean = 7 g kg^{-1} DM) and lower in *C. erecta* and *Z. fagara* (3.2 g kg^{-1} DM). The Mg content in all plants augmented as rainfall (r = 0.69; $p<0.001$) and temperature (r = 0.64; $p<0.001$) increased, being Summer and Autumn,

Table 3: Seasonal means of P content (g kg^{-1} DM) in native plants from Northeastern Mexico

Sites	Seasons	*C. erecta*	*C. pallida*	*F. angustifolia*	*L. macropoda*	*Z. fagara*
Los Ramones	Summer 2004	1.7	1.9	1.8	2.1	2.2
	Autum 2004	1.4	1.5	1.6	1.9	1.9
	Winter 2005	1.3	1.3	1.5	1.6	1.8
	Spring 2005	1.2	1.1	1.4	1.4	1.6
	Summer 2005	2.0	2.1	1.9	2.2	2.3
	Autum 2005	1.8	1.9	1.8	1.9	2.1
	Winter 2006	1.3	1.6	1.7	1.8	1.9
	Spring 2006	1.2	1.4	1.6	1.6	1.8
Linares	Summer 2004	1.9	2.4	2.1	2.6	2.6
	Autum 2004	1.8	2.2	1.9	2.4	2.3
	Winter 2005	1.6	2.0	1.8	1.8	2.0
	Spring 2005	1.4	1.9	1.7	1.6	1.9
	Summer 2005	2.3	2.8	2.3	3.7	2.7
	Autum 2005	2.0	2.5	2.1	2.9	2.4
	Winter 2006	1.8	2.3	1.9	2.5	2.1
	Spring 2006	1.5	2.0	1.8	2.1	2.0
China	Summer 2004	1.7	2.0	1.9	2.2	2.2
	Autum 2004	1.6	1.6	1.8	1.9	2.0
	Winter 2005	1.3	1.4	1.6	1.8	1.9
	Spring 2005	1.3	1.2	1.5	1.6	1.7
	Summer 2005	1.9	2.2	2.0	2.3	2.4
	Autum 2005	1.7	1.8	1.8	2.1	2.2
	Winter 2006	1.4	1.7	1.7	1.9	2.0
	Spring 2006	1.4	1.5	1.6	1.7	1.8
	Grand Mean	1.6	1.9	1.8	2.1	2.1
	SEM	0.02	0.02	0.01	0.02	0.01
	Effects	p	p	p	p	p
	Year (A)	<0.001	<0.001	<0.001	<0.001	<0.001
	Site (B)	<0.001	<0.001	<0.001	<0.001	<0.001
	Season (C)	<0.001	<0.001	<0.001	<0.001	<0.001
	A×B	<0.001	<0.001	<0.001	<0.001	<0.001
	A×C	<0.001	<0.001	<0.001	<0.001	<0.001
	B×C	<0.001	<0.001	<0.001	<0.001	<0.001
	A×B×C	<0.001	<0.001	<0.001	<0.001	<0.001

SEM = Standard Error of the Mean; n = 4; p = probability

Table 4: Seasonal means of Mg content (g kg^{-1} DM) in native plants from Northeastern Mexico

Sites	Seasons	*C. erecta*	*C. pallida*	*F. angustifolia*	*L. macropoda*	*Z. fagara*
Los Ramones	Summer 2004	4.8	7.4	5.1	4.1	3.1
	Autum 2004	3.6	7.0	4.3	3.9	2.9
	Winter 2005	3.0	5.8	3.5	3.7	2.7
	Spring 2005	3.4	4.4	2.9	3.5	2.5
	Summer 2005	3.1	7.6	5.5	4.5	3.2
	Autum 2005	2.6	7.3	4.7	4.1	2.9
	Winter 2006	2.8	6.5	3.8	3.8	2.8
	Spring 2006	2.5	5.6	3.2	3.6	2.4
Linares	Summer 2004	3.5	8.4	5.7	5.9	3.6
	Autum 2004	3.4	7.6	5.2	4.6	3.5
	Winter 2005	3.2	6.9	4.8	4.1	3.2
	Spring 2005	3.1	6.2	4.3	3.8	3
	Summer 2005	3.9	9.6	6.5	6.1	4.5
	Autum 2005	3.7	8.2	5.9	5.6	3.9
	Winter 2006	3.4	7.2	5.3	4.8	3.6
	Spring 2006	3.2	6.9	4.6	4.2	3.4
China	Summer 2004	3.2	7.7	5.2	5.6	3.6
	Autum 2004	3.1	7.2	4.6	4.6	3.3
	Winter 2005	2.8	6.2	3.7	3.8	2.7
	Spring 2005	2.9	6.1	3.2	3.6	2.6
	Summer 2005	4.1	7.8	5.6	5.8	3.6
	Autum 2005	3.6	7.5	4.8	5.4	3.1
	Winter 2006	3.1	6.8	3.9	4.8	2.9
	Spring 2006	2.8	5.8	3.3	3.8	2.6
	Grand Mean	3.2	7.0	4.6	4.5	3.2
	SEM	0.04	0.1	0.02	0.02	0.02
	Effects	p	p	p	p	p
	Year (A)	<0.001	<0.001	<0.001	<0.001	<0.001
	Site (B)	<0.001	<0.001	<0.001	<0.001	<0.001
	Season (C)	<0.001	<0.001	<0.001	<0.001	<0.001
	A × B	<0.001	<0.001	<0.001	<0.001	<0.001
	A × C	<0.001	<0.001	<0.001	<0.001	<0.001
	B × C	<0.001	<0.001	<0.001	<0.001	<0.001
	A × B × C	<0.001	<0.001	<0.001	<0.001	<0.001

SEM = Standard Error of the Mean; n = 4; p = probability

of both years, higher than Winter and Spring. It seems that all studied plants, in all seasons had Mg contents to meet adult white-tailed deer of 1.0 g kg^{-1} DM (NRC, 2007). Thomas *et al.* (1990) reported a very similar range (1.1-8.0 g kg^{-1} DM) in 18 shrubs that growth in Texas, USA. Moreover, other studies have found that diets from esophageal samples by range goats growing in North Mexico (Cerrillo-Soto *et al.*, 2004) or browse plants from Northeastern (Ramirez *et al.*, 2001) and Northwestern (Ramirez-Orduna *et al.*, 2005) Mexico had sufficient amounts of Mg to meet requirements of adult small ruminants. Magnesium deficiency is associated with hypomagnesemic tetany but ordinarily this condition is less common in range small ruminant than in cattle. Goats and white-tailed deer have marginal ability to compensate for low magnesium by decreasing the amount of magnesium they excrete (Underwood and Shuttle, 1999). Both urinary excretion and milk production are reduced in a magnesium deficiency (McDowell, 2003).

Sodium content (Table 5) resulted higher in *F. angustifolia* (2.0 g kg^{-1} DM) and lower in *C. erecta* (1.7 g kg^{-1} DM). It appears that most plants can be considered as Na non-accumulators because they contain less that 2.5 g kg^{-1} DM (Youssef, 1988). In this study, rainfall ($r = 0.70$; $p<0.001$) and temperature ($r = 0.74$; $p<0.001$) influenced Na content in all plants. During all seasons most plants had Na content to meet the needs of white-tailed deer (1.0 g kg^{-1} DM; NRC, 2007). High K content (range = 7-21 g kg^{-1} DM) in studied plants could reduce Na absorption of range ruminants feeding with these plants since it has been reported that elevated dietary in K may decrease ruminal concentration and absorption of Na in sheep and steers (Spears, 1994). In this study, all evaluated shrubs had Na contents that increased as rainfall ($r = 0.66$; $p<0.001$) and temperature ($r = 0.67$; $p<0.001$) augmented.

Salt (NaCl) is usually recognized as a necessary dietary component but is often forgotten. Range small ruminants may consume more salt than is required when it is offered *ad libitum*; this does not present a nutritional problem but may depress feed and water intakes in some arid regions where salt content of the drinking water is quite high. Salt formulations are used as carriers of trace minerals as range ruminants have a clear drive for Na intake. Lactating ruminants often requires additional salt as milk contains high amounts of Na (Whitehead, 2000).

Table 5: Seasonal means of Na content (g kg^{-1} DM) in native plants from Northeastern Mexico

Sites	Seasons	*C. erecta*	*C. pallida*	*F. angustifolia*	*L. macropoda*	*Z. fagara*
Los Ramones	Summer 2004	2.2	1.6	2.1	1.8	1.9
	Autum 2004	2.1	1.5	1.9	1.7	1.7
	Winter 2005	1.5	1.4	1.7	1.6	1.5
	Spring 2005	1.4	1.3	1.5	1.2	1.4
	Summer 2005	1.4	1.8	2.2	1.9	2
	Autum 2005	1.3	1.6	2	1.7	1.8
	Winter 2006	1.6	1.5	1.8	1.7	1.6
	Spring 2006	1.3	1.4	1.6	1.4	1.5
Linares	Summer 2004	3.2	2.7	2.4	2.7	2.5
	Autum 2004	2.9	2.5	2.2	2.6	2.3
	Winter 2005	1.3	2.2	2.0	1.8	1.9
	Spring 2005	1.7	2.1	1.8	1.7	1.7
	Summer 2005	3.1	2.8	2.6	2.9	2.6
	Autum 2005	2.8	2.6	2.4	2.7	2.5
	Winter 2006	1.4	2.3	2.1	1.9	2.2
	Spring 2006	1.6	2.2	1.9	1.7	1.9
China	Summer 2004	1.8	1.7	2.2	1.9	2.1
	Autum 2004	1.7	1.6	2.0	1.8	1.8
	Winter 2005	1.5	1.5	1.8	1.6	1.6
	Spring 2005	1.2	1.4	1.6	1.3	1.5
	Summer 2005	1.8	1.9	2.3	2.0	2.2
	Autum 2005	1.7	1.7	2.2	1.8	2.0
	Winter 2006	1.2	1.6	2.0	1.5	1.8
	Spring 2006	1.1	1.5	1.7	1.4	1.7
	Grand Mean	1.7	1.9	2.0	1.8	1.9
	SEM	0.2	0.1	0.1	0.1	0.2
	Effects	p	p	p	p	p
	Year (A)	<0.001	<0.001	<0.001	<0.001	<0.001
	Site (B)	<0.001	<0.001	<0.001	<0.001	<0.001
	Season (C)	<0.001	<0.001	<0.001	<0.001	<0.001
	A×B	<0.001	<0.001	<0.001	<0.001	<0.001
	A×C	<0.001	<0.001	<0.001	<0.001	<0.001
	B×C	<0.001	<0.001	<0.001	<0.001	<0.001
	A×B×C	<0.001	<0.001	<0.001	<0.001	<0.001

SEM = Standard Error of the Mean; n = 4; p = probability

Table 6: Seasonal means of K content (g kg^{-1} DM) in native plants from Northeastern Mexico

Sites	Seasons	*C. erecta*	*C. pallida*	*F. angustifolia*	*L. mac ropoda*	*Z. fagara*
Los Ramones	Summer 2004	7	18	21	22	12
	Autum 2004	7	14	19	21	11
	Winter 2005	5	12	17	18	10
	Spring 2005	6	10	15	17	10
	Summer 2005	7	19	22	22	13
	Autum 2005	7	17	20	21	13
	Winter 2006	6	15	17	19	12
	Spring 2006	5	13	16	17	10
Linares	Summer 2004	9	20	24	25	16
	Autum 2004	8	17	20	23	15
	Winter 2005	8	15	18	21	14
	Spring 2005	7	14	17	19	13
	Summer 2005	9	22	25	26	18
	Autum 2005	8	20	23	24	17
	Winter 2006	7	18	21	21	14
	Spring 2006	7	16	19	21	14
China	Summer 2004	7	19	21	22	14
	Autum 2004	7	15	20	21	13
	Winter 2005	6	13	17	20	11
	Spring 2005	6	11	16	17	10
	Summer 2005	8	20	23	24	15
	Autum 2005	7	18	20	22	14
	Winter 2006	7	16	19	20	13
	Spring 2006	6	14	17	18	12
	Grand Mean	7	16	20	21	13
	SEM	0.1	0.2	0.1	0.1	0.3
	Effects	p	p	p	p	p
	Year (A)	<0.001	<0.001	<0.001	<0.001	<0.001

Table 6: Continue

Sites	Seasons	*C. erecta*	*C. pallida*	*F.angustifolia*	*L. macropoda*	*Z. fagara*
	Site (B)	<0.001	<0.001	<0.001	<0.001	<0.001
	Season (C)	<0.001	<0.001	<0.001	<0.001	<0.001
	A×B	<0.001	<0.001	<0.001	<0.001	<0.001
	A×C	<0.001	<0.001	<0.001	<0.001	<0.001
	B×C	<0.001	<0.001	<0.001	<0.001	<0.001
	A×B×C	<0.001	<0.001	<0.001	<0.001	<0.001

SEM = Standard Error of the Mean; n = 4; p = probability

During Summer all plants had higher K than in other seasons (Table 6), particularly was higher in *L. macropoda* (21 g kg^{-1} DM) and lower in *C. erecta* (7 g kg^{-1} DM). Seasonal variation in K content might be related to water availability because K absorption by the root is linked to the soil moisture (McDowell, 2003). It seems that adult range white-tailed deer consuming these plants could acquire substantial amounts of K to meet their requirements of K in all seasons (6.0 g kg^{-1} DM; NRC, 2007). Similar findings were reported to ruminants by Greene *et al*. (1987), Ramirez *et al*. (2001), Cerrillo-Soto *et al*. (2004) and Guerrero-Cervantes (2009) who evaluated K content in browse species growing in arid and semiarid regions of the world. Considering all required minerals, K is most affected by forage maturity. Young actively growing forage may contain excess K in the range of 4-5% while mature forages are often <0.4-0.5%. Potassium in milk is not affected by diet, season or stage of lactation; this is generally true for all macro minerals (McDowell, 2003). The main reason for lack of widespread K deficiency even when forages contain lower than the minimum requirements is likely due to the deficiencies of other nutrients in forages. It is expected that K deficiency will not be expressed as long as there are other nutrients that are even more deficient (McDowell and Valle, 2000).

CONCLUSION

The Ca, Mg, Na and K content in the five shrubs studied were in sufficient amounts to meet the requirements, all year around of adult white-tailed deer while P contents were deficient in most seasons. Most plants had higher levels of the determined minerals during Summer and Autumn when rainfall and temperature were high. Thus, results of the present study may suggest that even though all plants differed in mineral content and followed a seasonal pattern, during adequate or adverse conditions such as extreme temperatures and water shortages, they still could play important roles in maintaining the productivity of dry rangeland ecosystems.

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