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Chemical Composition, Digestion and Mineral Content of Native Forbs Consumed by Range Sheep

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Abstract: Native forbs from northeastern Mexico such as *Coldenia greggii* (T and G) Gray., *Dyssodia pentachyata* (DC) Robins, *Happlopapus spinolosus* (Greene) Hall., *Heliotropium angiospermun* (Murr.), *Palafoxia texana* DC., *Polyanthes maculosa* (Hook) Shinners., *Ruellia corzoi* (Tram and Burlk.), *Sida filicaulis* (T and G.) and *Zephyranthes arenicola* (Hemsl.) that are consumed by range sheep were evaluated to estimate the seasonal content of ash, Crude Protein (CP), neutral detergent fiber (NDF), lignin, Ca, P, K, Mg, Na, Cu, Fe, Zn, Mn and the rate and extent of Dry Matter (DM) digestion. The nylon bag technique was used to estimate effective degradability of DM (EDDM). In all forbs during spring and autumn when precipitation was higher, ash (25 and 27%), CP (16 and 18%) and EDDM (71 and 74%, respectively) were higher than other seasons. On the contrary, NDF (37 and 36%) and lignin (6 and 6%, respectively) were lower. It was estimated that an adult range sheep, consuming these forbs, could eat substantial amounts of Ca, K, Mg, Cu, Fe, Mn and Zn in all seasons. Phosphorous (in all seasons) and Na (in winter and summer) were marginally deficient in most forbs. Because of their high nutritional quality especially, during spring and autumn, all evaluated forbs could be considered prominent food resources for range sheep.

Key words: Adult range sheep, chemical composition, effective degradability of dry matter, native mexican forbs

INTRODUCTION

Knowledge of range sheep nutritional requirements and how well those needs are met by the forage provided is essential. Only after the relative seasonal availability of nutrients is known can sheep be managed to obtain a maximum return, from the available resources produced in rangelands from northeastern, Mexico and southern, US. However, in these regions forb growth is highly dependent on adequate moisture and mild temperatures [1]. Nevertheless, there is considerable evidence, that including native forbs in diets of range animals improves animal performance, during periods when grasses are dormant and low in quality[2]. Comparative studies[3] show that Crude Protein (CP), Fiber (NDF), ash and P content, in 83 native forbs collected at different parts of the world, influence positively *in Vitro* Dry Matter Digestibility (IVDMD). Moreover, CP was higher and NDF lower in spring and autumn seasons of several native forbs growing in Texas, US, with no significant differences among seasons in P, Ca, K, Mg, Na[4,5].

Most previous research, on range forages, has focused primarily on quantifying IVDMD, CP, P and energy content; however, limited quantitative information is available on seasonal dynamics of macro and trace essential minerals contained in range forbs[6] even though, minerals influence forage quality and can depress digestibility and feed intake when levels are low[7]. Moreover, some of them can inhibit ruminal bacterial growth and their multiplication[8] and can affect the capacity of cellulolitic bacteria to add to fiber[9]. The objectives of this study were to estimate and compare seasonally, the chemical composition, mineral profile and ruminal digestion of preferred sheep native forbs from northeastern México.

MATERIALS AND METHODS

The study was carried out in a rangeland area of approximately 20 ha at the Agricultural Experimental Station of Facultad de Agronomía, Universidad Autónoma de Nuevo León at Marín, County, N.L., México. Marín is located at 25° 43′ north latitude and 100° 02′ west longitude. The average elevation is 393 m. The climate of the region is considered semiarid with an annual mean temperature of 22°C an about 500 mm of rainfall which is bimodal, with peaks occurring in spring and autumn. Autumn rainfall appears to be the most

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reliable for quantity received. Average precipitation, by month, ranges from 20 cm to 140 cm, but six to eight months of the year are relatively dry. Rainfall is also very erratic. Droughts are also common and frequently are severe. During the study, rainfall was 61.6 mm in winter, 140.2 in spring, 73.0 in summer and 144.1 in fall. Most soils of the region are rocky type of Upper Cretaceous calcite and dolomite. Dominants are deep, dark gray, lime-clay Vertisoles which are the result of alluvial and colluvial processes. They are characterized by high clay and calcium carbonate contents, pH varies from 7.5 to 8.5 and low organic matter content[10].

Perennial forbs such as *Coldenia greggii* (T and G) Gray., *Dyssodia pentachyata* (DC) Robins, *Happlopapus spinolosus* (Greene) Hall., *Heliotropium angiospermum* (Murr.), *Palafoxia texana* DC., *Polyanthes maculosa* (Hook) Shinners., *Ruellia corzoi* (Tram and Burlk.), *Sida filicaulis* (T and G.), *Zephyranthes arenicola* (Hemsl.) that are consumed by range sheep[1] were collected for nutritional studies. As encountered in the range, forbs were hand harvested in four sites, in the same area, until adequate amounts of material were obtained and composite by species and sites in each of the four seasons of 2001. The complete plants were stored in paper bags in the field and transported to laboratory. The sites of collection were grazed by livestock. Partial dry matter contents were determined by oven drying at 55 C during 72 h then samples were ground in a Wiley mill (1 mm) and stored in plastic containers for further analyses.

Samples were analyzed for dry matter (DM), ash, CP, lignin[11,12]. Mineral content was estimated by incinerating the samples in a muffle at 550 C during 5 hours. Ashes were digested in a solution containing HCl y HNO_3, using the wet digestion technique[13]. 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[11] .

The rate and extent of DM loss was estimated using the nylon bag technique. Four rumen cannulated Pelibuey x Rambouillet sheep (weighing 45±3.5 kg, BW) were used to incubate the nylon bags (5×10 cm, 53 μm of pore size), which contained ground (4 g) samples of each forb species. During the trial, sheep were fed alfalfa hay *ad libitum*. Incubation periods were at 4, 8, 12, 24, 36 and 48 h. Upon removal from the rumen, bags were washed in cold water. Zero time disappearance was obtained by washing unincubated bags in similar fashion and then bags were dried at 55°C in an oven for 48 h. Disappearance of DM for each incubation period was calculated by:

DM disappearance, % = (Initial weight-final weight)/(initial weight)×100

Digestion characteristics of DM were calculated using the equation of ørskov and McDonald (1979):

$$p = a+b\,(1-e^{-ct})$$

Where:

- p is disappearance rate of DM at time t,
- a is an intercept representing the portion of DM solubilized at the beginning of incubation (time 0),
- b is the portion of DM that is slowly degraded in the rumen,
- c is the rate constant of disappearance of fraction b and
- t is the time of incubation.

The nonlinear parameters a, b and c and effective degradability of DM (EDDM) = $(a+b)c/(c+k)(e^{-(ct)LT})$, were calculated using the Neway computer program[14]; k is the estimated rate of rumen out flow and LT is the time lag. The EDDM of samples were estimated assuming a rumen out flow rate of 2 % h^{-1}.

Data were statistically analyzed using an experimental design of two ways of classification (being forbs and seasons the study factors), with interaction between seasons and forbs. The interaction seasons x grasses was significant ($p<0.05$), thus analyses of variance were carried out among seasons and among forbs within seasons. Partial correlation coefficients were performed between chemical composition, seasonal precipitation and temperatures and EDDM[15].

RESULTS AND DISCUSSION

With exception of *H. angiospermum*, CP content in all forbs was significantly different among seasons and among grasses within seasons. *Zephyranthes arenicola* was higher and *D. pentachyata* was lower. All forbs exhibited higher ($p<0.001$) CP concentrations in spring and autumn seasons Table 2. Seasonal fluctuations in CP content may be induced by spring and autumn (140.2 and 144.1 mm, respectively) rainfall. This fact can be explained because plant protein increases during growth or regeneration when active anabolic processes are occurring, but then it decreases with increasing maturity as greater emphasis is placed on the production of nitrogen-free NDF components for structural support[16]. In this study, NDF Table 2 and its components (cellulose and hemicellulose and lignin; Table 3) were influenced by the climatic conditions; in those seasons when rainfall was higher (spring and autumn), invariably NDF and lignin content were lower.

Table 1: Comparative studies showing means of nutritive value (% DM basis) of range forbs collected in different locations and predictive linear equations of IVDMD calculated form the same data

No. of forbs	Location	CP	NDF	Ash	P	IVDMD	References
5	Oregon, US	9	40	10	1.6	63	Damiran *et al.*,[22]
6	Nigeria, Africa	6	42	7	1.6	49	Kallah *et al.*,[23]
2	Texas, US	9	29	12	1.3	61	Richarson,[24]
46	Northern, Australia	9	35	8	1.1	51	Bastin,[25]
2	Texas, US	19	30	10	2.0	63	Meyer and Brown,[20]
18	Texas, US	15	32	9	1.8	59	Everitt and Gonzalez,[5]
20	Texas, US	16	33	11	2.0	61	Huston *et al.*,[27]

Dependent variable	Intercept	Slope	Independent variables	r	Level of significance
IVDMD	78.3	-0.59	NDF	-0.56	p<0.001
IVDMD	49.1	0.72	CP	0.36	p<0.05
IVDMD	50.4	0.52	P	0.35	p<0.05
IVDMD	30.2	2.81	Ash	0.81	p<0.001

CP = crude protein; NDF = neutral detergent fiber; P = phosphorous; IVDMD = in vitro DM digestibility

Table 2: Seasonal trends of crude protein and neutral detergent fiber content in nine native forbs growing in northeastern Mexico

	Crude protein, % DM							Neutral detergent fiber, % DM						
	Seasons							Seasons						
Forbs	w	sp	su	f	Mean	SEM	Sig	w	sp	su	f	Mean	SEM	Sig
C. greggii	13	13	14	14	14	0.1	**	47	43	46	44	45	0.3	**
D. pentachyata	9	10	11	13	11	0.2	***	55	43	54	46	50	0.1	***
H. spinolosus	14	15	15	16	15	0.1	***	39	38	39	36	38	0.1	*
H. angiospermum	20	20	19	21	20	0.9	NS	42	37	42	35	39	0.2	***
P. texana	16	15	18	19	17	0.1	***	40	39	42	36	39	0.1	***
P. maculosa	12	9	12	15	12	0.1	***	26	24	25	24	25	0.1	*
R. corzoi	17	16	15	19	17	0.1	***	46	42	43	40	43	0.2	**
S. filicaulis	15	18	15	19	17	0.1	***	36	36	34	32	35	0.3	*
Z. arenicola	22	24	23	26	24	1.0	***	33	29	30	28	30	0.8	***
Mean	15	16	16	18	16			40	37	39	36	38		
SEM	1.0	1.0	1.2	1.0	0.8			1.4	1.4	1.3	1.4	0.5		
Significance	***	***	***	***	***			***	***	***	***	***		

w = winter; sp = spring; su = summer; f = fall; SEM = standard error of the mean; Sig= significance; **(p<0.01); ***(p<0.001); NS = no significant

Table 3: Seasonal variation of concentration of cellulose, hemicellulose, lignin (% DM) and the portion of DM solubilized at the beginning of incubation (a) in nine native forbs growing in northeastern Mexico

	Cellulose, % DM							Hemicellulose, % DM						
	Seasons							Seasons						
Forbs	W	sp	su	f	Mean	SEM	Sig	w	sp	su	f	Mean	SEM	Sig
C. greggii	24	22	23	22	23	0.4	**	9	6	8	6	7	0.2	***
D. pentachyata	32	30	34	22	30	0.1	***	13	9	11	9	11	0.1	***
H. spinolosus	17	16	16	15	16	0.1	**	12	10	10	9	10	0.1	***
H. angiospermum	20	18	18	17	18	0.3	***	15	11	16	9	13	0.1	***
P. texana	16	15	14	14	15	0.3	**	19	16	20	14	17	0.2	***
P. maculosa	13	11	10	9	11	0.2	***	9	8	8	7	8	0.2	*
R. corzoi	20	14	15	12	15	0.3	***	15	13	16	11	14	0.1	***
S. filicaulis	18	18	19	17	18	0.1	*	15	13	13	10	13	0.2	***
Z. arenicola	19	18	18	16	18	1.1	***	6	5	6	4	5	0.7	**
Mean	20	18	19	16	18			13	10	12	9	11		
SEM	0.9	1.0	1.1	1.2	0.9			0.8	0.8	0.9	0.9	1.0		
Significance	***	***	***	***	***			***	***	***	***	***		
	Lignin, % DM							a, % DM						
C. greggii	8	7	9	6	8	0.1	***	35	35	34	30	34	0.3	**
D. pentachyata	11	10	10	9	10	0.3	NS	35	26	21	32	29	0.3	***
H. spinolosus	10	10	11	9	10	0.3	***	37	40	40	42	40	0.2	***
H. angiospermum	7	6	8	7	7	0.1	NS	42	34	38	41	39	0.3	***
P. texana	6	4	6	5	5	0.1	***	39	53	50	52	49	0.4	***
P. maculosa	5	4	5	3	4	0.2	NS	72	64	64	62	65	0.3	***
R. corzoi	9	8	8	6	8	0.2	***	37	36	37	39	37	0.4	NS
S. filicaulis	5	5	6	4	5	0.1	***	42	39	42	48	43	0.2	***
Z. arenicola	3	2	4	3	3	0.7	NS	67	47	57	59	57	0.6	***
Mean	7	6	7	6	7			45	42	43	45	44		
SEM	0.9	0.9	1.5	1.0	0.6			1.1	1.1	1.1	1.2	1.7		
Significance	***	***	***	***	***			***	***	***	***	***		

w = winter; sp = spring; su = summer; f = fall; SEM = standard error of the mean; Sig = significance; *(p<0.05); **(p<0.01); ***(p<0.001); NS = no significant.a = intercept representing the portion of DM solubilized at the beginning of incubation (time 0)

The fraction of DM solublized at the beginning of incubation of grasses in the rumen of sheep a; Table 3, the fraction of DM that is slowly degraded in the rumen (b) and the rate constant of disappearance of fraction c were significantly different among seasons and among most forbs within seasons. With exception of *S. filicaulis*, EDDM in all forbs was significantly different among seasons and among all forbs within seasons Table 4. *Polyanthes maculosa and Z. arenicola* were higher and *D. pentachyata* was lower. The CP content in forbs positively influenced the rumen digestion of DM, because when CP increased ($r = 0.41$; $p<0.001$) also increased EDDM. Conversely, when NDF ($r = -0.81$; $p<0.001$) or lignin increased ($r = -0.63$; $p<0.001$) EDDM was depressed. This fact can be explained because as plant cells mature, cell walls increase in thickness and amount of fiber. The increase in fiber results in decreased DM digestibility[17]. Moreover, comparative data of seven studies Table 1 show also that NDF ($r = -0.56$; $p<0.001$), ash ($r = 0.81$; $p<0.001$), P ($r = 0.35$; $p<0.05$) and CP ($r = 0.36$; $p<0.05$) content, influenced IVDMD of forbs collected in different parts of the world.

With exception of *C. greggii* and *Z. arenicola* all forbs had Ca content that was significantly different among seasons and among forbs within seasons. *Coldenia greggii* was higher and *P. texana* was lower Table 4. Adult range sheep require in their diets about 5.0 g of Ca kg^{-1} DM[18] In this study, all forbs, in all seasons, had Ca content to meet requirements. Only *C. greggii*, *P texana* and *P maculosa* had P content that was significantly different among seasons; however, all forbs were significant different within seasons Table 5. *Zephyranthes arenicola* had higher P content and *C. greggii* was lower. It seems that only *Z. arenicola* had marginal sufficient P content, in all seasons, to meet the needs 2.7 g. kg^{-1} DM;[18] of adult range sheep. It seems that P deficiencies are mainly associated to the low mineral concentration in soils[19]. In this study, Ca concentration in all forbs was well above minimum requirements. Perhaps of more importance than actual Ca levels is the Ca:P ratio. A 2:1 ratio is best for optimum utilization and metabolism of both elements, although higher ratios are acceptable if adequate vitamin D is available[9]. In this study, the Ca: P ratios varied from 11:1 in *C. greggii* to 40:1 in *P. texana.*

With exception of *S. filicaulis* K content was significantly different among seasons and among forbs within seasons. *Zephyranthes arenicola* was higher and *C. greggii* was lower. During spring and autumn all forbs resulted with significantly higher K content Table 5. It appears that all forbs had sufficient K, in all seasons, to satisfy adult range sheep requirements (6.0 g.kg^{-1} DM; [18]. With exception of *H. spinolosus* Mg content was significantly different among seasons and among all

Table 4: Seasonal parameters of *in situ* digestibility, effective degradability of DM and Ca content in nine native forbs growing northeastern Mexico

Grasses	b, % DM							c, % DM						
	Seasons							Seasons						
	w	sp	su	f	Mean	SEM	Sig	w	sp	su	f	Mean	SEM	Sig
C. greggii	31	41	37	46	39	0.5	***	6	7	7	9	7	0.01	***
D. pentachyata	33	32	23	31	30	0.3	***	7	7	6	8	7	0.02	***
H. spinolosus	33	38	36	36	36	0.3	**	8	8	8	8	8	0.01	NS
H. angiospermum	35	37	35	34	35	0.5	NS	5	8	6	9	7	0.01	***
P. texana	27	43	33	39	35	0.2	***	10	10	11	11	10	0.01	**
P. maculosa	24	33	22	32	28	0.3	***	12	13	8	10	11	0.03	*
R. corzoi	48	38	45	62	48	0.4	***	7	8	6	7	7	0.03	NS
S. filicaulis	42	39	42	46	43	0.3	***	9	9	9	11	9	0.04	NS
Z. arenicola	31	37	36	42	36	0.4	***	15	15	12	14	14	0.03	NS
Mean	34	38	34	41	37			9	9	8	10	9		
SEM	1.1	1.2	1.2	1.5	1.8			0.01	0.1	0.1	0.2	0.1		
Significance	***	***	***	***	***			***	***	***	NS	NS		
	Effective degradability of DM, % DM							Ca, g kg^{-1} DM						
C. greggii	57	61	58	66	60	1	***	50	48	47	49	49	0.3	NS
D. pentachyata	50	55	39	55	50	2	***	24	26	32	44	32	0.3	***
H. spinolosus	61	66	65	70	66	3	**	27	36	34	48	36	0.1	***
H. angiospermum	65	69	57	64	64	2	***	35	36	39	37	37	0.1	***
P. texana	73	77	58	83	73	3	***	17	15	22	18	18	0.1	***
P. maculosa	88	85	81	85	85	1	**	38	22	34	36	33	0.3	***
R. corzoi	69	66	68	76	70	2	**	39	32	43	42	39	0.2	***
S. filicaulis	75	74	74	76	74	2	NS	22	17	28	21	22	0.1	***
Z. arenicola	87	87	86	89	85	2	**	23	23	24	23	23	0.8	NS
Mean	69	71	65	74	70			31	28	34	35	32		
SEM	2	3	2	2	3			1.1	1.2	1.1	1.2	1.5Significance		* * *
	***	***	***	***			***	***	***	***	***			

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.b = portion of DM that is slowly degraded in the rumen. c = rate constant of disappearance of fraction b.EDDM = effective degradability of dry matter at a rumen outflow rate of 2.5 % h^{-1}

forbs within seasons. *Heliotropium angiospermum* and *R. corzoi* were higher and *H. spinolosus* and *C. greggii*, *H. spinolosus* and *Z, arenicola* were lower Table 5. Adult range sheep require 1.5 g kg^{-1} in the DM of their diets[18]. In this study, all forbs, in all seasons, had sufficient Mg content to meet sheep requirements.

Evaluated Forbs can be considered as Na non-accumulators because they contain less that 2 g Na kg^{-1} DM[20] and is the most commonly deficient in northern ecosystems and the only nutrient for which herbivores appear to develop a highly specific appetite[18]. In this study, during winter most forbs had lower Na content Table 5 to meet the needs of an adult range sheep 0.7 g kg^{-1} DM;[18]. High K content might have reduced Na absorption of sheep feeding these forbs, because it has been reported that elevated dietary K may decrease ruminal concentration and absorption of Na in sheep and steers[21]. However, Na deficiency can be alleviated by supplementing sheep with common salt.

Copper, Fe, Mn and Zn content, in all forbs, were significantly different among seasons and among forbs within seasons. During spring and fall were higher ($p<0.001$) than other seasons Table 6. Adult range sheep requires 9.0, 40.0, 30 and 30 mg kg^{-1} DM in their diets, respectively. In this study, all forbs, in all seasons, had Cu, Fe, Mn and Zn content to satisfy requirements[18].

Table 5: Seasonal concentrations of P, K, Mg and Na in forbs growing in northeastern Mexico

Grasses	P, g kg⁻¹ DM							K, g kg⁻¹ DM						
	Seasons							Seasons						
	w	sp	su	f	Mean	SEM	Sig	w	sp	su	f	Mean	SEM	Sig
C. greggii	0.8	1.2	1.4	1.5	1.2	0.1	***	11	18	12	19	15	0.2	***
D. pentachyata	1.3	1.5	1.3	1.7	1.5	0.03	NS	12	15	14	21	16	0.1	***
H. spinolosus	1.4	1.6	1.6	1.6	1.6	0.1	NS	15	19	18	20	18	0.2	***
H. angiospermum	1.7	1.9	1.9	2.1	1.9	0.04	NS	23	27	27	30	27	0.2	***
P. texana	1.3	1.7	1.6	1.9	1.6	0.03	***	27	32	30	32	30	0.2	***
P. maculosa	1.5	2.3	1.9	2.3	2.0	0.04	***	20	25	27	31	26	0.4	***
R. corzoi	1.5	1.7	1.5	1.7	1.6	0.1	NS	23	23	23	25	24	0.1	***
S. filicaulis	1.1	1.4	1.4	1.6	1.4	0.1	NS	29	31	28	31	30	0.8	NS
Z. arenicola	2.7	2.7	2.8	3	2.8	0.4	NS	27	33	33	37	33	0.2	***
Mean	1.5	1.8	1.7	1.9	1.7			21	25	24	27	24		
SEM	0.2	0.2	0.2	0.2	0.1			1.1	1.0	1.8	1.4	1.0		
Significance	***	***	***	***	***			***	***	***	***	***		
	Mg, g kg⁻¹ DM							Na, g kg⁻¹ DM						
C. greggii	4	4	5	8	5	0.1	***	0.6	0.7	0.6	0.7	0.7	0.02	NS
D. pentachyata	4	4	4	6	5	0.2	*	0.5	1.0	0.8	1.3	0.9	0.04	NS
H. spinolosus	4	4	4	5	4	0.1	NS	0.6	0.7	0.7	0.7	0.7	0.04	NS
H. angiospermum	9	10	8	16	11	0.1	***	1.5	1.5	1.8	2.4	1.8	0.02	***
P. texana	8	7	9	11	9	0.1	***	0.6	1.5	0.7	1.6	1.1	0.02	***
P. maculosa	6	5	7	7	6	0.1	**	0.6	0.7	0.6	0.8	0.7	0.01	***
R. corzoi	11	11	10	13	11	0.4	***	0.6	0.7	0.7	0.7	0.7	0.02	***
S. filicaulis	6	5	6	7	6	0.1	***	0.7	0.8	0.8	1.6	1.0	0.1	NS
Z. arenicola	4	5	5	6	5	0.4	***	0.5	0.6	0.6	0.6	0.6	0.1	NS
Mean	6	6	6	9	7			0.7	0.9	0.8	1.2	0.9		
SEM	0.6	0.6	0.6	0.5	0.5			0.1	0.1	0.1	0.2	0.1		
Significance	***	***	***	***	***			NS	***	***	***	***		

w = winter; sp = spring; su = summer; f = fall; SEM = standard error of the mean; Sig= significance; *($p<0.05$); **($p<0.01$); ***($p<0.001$); NS = no significant.

Table 6: Seasonal content of Cu, Fe, Mn and Zn in nine forbs growing in northeastern Mexico

Grasses	Cu, mg kg⁻¹ DM							Fe, mg kg⁻¹ DM						
	Seasons							Seasons						
	W	sp	su	f	Mean	SEM	Sig	w	sp	su	f	Mean	SEM	Sig
C. greggii	10	17	10	17	14	0.4	***	145	197	148	201	173	9	***
D. pentachyata	12	15	13	20	15	0.4	***	212	257	223	376	267	11	***
H. spinolosus	11	16	15	18	15	0.2	***	178	200	193	213	196	9	***
H. angiospermum	16	19	18	21	19	0.2	***	112	158	151	181	151	7	***
P. texana	12	16	14	16	15	0.2	***	181	223	202	315	230	9	***
P. maculosa	11	12	12	14	12	0.1	***	114	330	121	446	253	12	***
R. corzoi	16	16	15	18	16	0.04	***	219	394	346	524	371	14	***
S. filicaulis	12	13	13	14	13	0.03	***	265	426	390	623	426	17	***
Z. arenicola	17	19	19	20	19	0.4	***	359	427	399	526	428	2	***
Mean	13	16	14	18	15			198	290	241	378	277		
SEM	0.8	1.0	0.8	1.1	0.8			10	12	8	14	19		
Significance	***	***	***	***	***			***	***	***	***	***		

Table 6: Continued.

	Mn, mg kg^{-1} DM							Zn, mg kg^{-1} DM						
C. greggii	45	59	55	59	55	1	***	50	68	61	87	67	2	***
D. pentachyata	42	47	43	51	46	1	***	49	67	59	77	63	2	***
H. spinolosus	48	51	50	51	50	1	***	48	58	50	69	56	2	***
H. angiospermun	40	43	43	51	44	1	***	50	55	52	64	55	1	***
P. texana	51	65	54	88	65	1	***	40	42	46	64	48	2	***
P. maculosa	40	50	45	50	46	1	***	34	48	37	67	47	1	***
R. corzoi	43	58	55	67	56	1	***	35	38	37	46	39	1	***
S. filicaulis	77	81	81	85	81	1	***	35	42	36	63	44	2	***
Z. arenicola	71	85	75	97	82	2	***	32	44	41	51	42	2	***
Mean	51	60	56	67	58			41	51	47	65	51		
SEM	1	1	1	1	3			3	3	3	3	4		
Significance	***	***	***	***	***			***	***	***	***	***		

w = winter; sp = spring; su = summer; f = fall; SEM = standard error of the mean; Sig = significance; *(p<0.05); **(p<0.01); ***(p<0.001); NS = no significant.

CONCLUSIONS AND MANAGEMENT IMPLICATIONS

In all forbs, CP and mineral content were influenced by climatic conditions. In general, higher levels were observed in spring and autumn seasons. The same pattern occurred for EDDM. Conversely, cell wall and lignin content were lower in spring and autumn. Calcium, Mg, K, Cu, Fe, Mn and Zn, in all forbs, were in sufficient amounts to meet the requirements of adult range sheep. Phosphorous was marginally deficient in all seasons and Na in winter. Thus, the provision of 1:1 mixture of dicalcium phosphate and salt with molasses (throughout the year), usually ensures sufficient intakes of P and Na. Interference between mineral levels during most seasons needs to be considered. Range managers should practice management techniques which provide a diversity of plant species, allowing grazing ruminants the opportunity to select the highest quality diet available. Common brush management technique such as creating a vegetational mosaic using root plowing o shredding will open the canopy. This will allow an increase in native forbs diversity and density, with its associated increase in nutritional value. In this study, all native forbs could be considered prominent food components for range sheep because of their high nutritional quality.

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