Morphology and forage quality in buffel, rhodes, and blue grama grasses in Valle del Mezquital

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ABSTRACT
This study aims to evaluate the production and quality of buffel (*Pennisetum ciliare*), rhodes (*Chloris gayana*), and blue grama (*Bouteloua gracilis*) forage with three defoliation dates —at 50, 80, and 110 days after regrowth (dar)— in Valle del Mezquital. Crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), total digestible nutrients (TDN), relative feed value (RFV), and metabolizable energy (ME) were determined. A completely randomized design with three repetitions, a Tukey test for mean separation (α=0.05), and SAS Proc GLM for data analysis were used. The highest forage production occurs in the rhodes forage at 110 dar (12,936 kg DM ha^{-1}). The highest CP (10.6%) was found in the buffel forage at 50 dar; in the rhodes forage, both values (80 and 110) were lower than 7%. The highest RFV was obtained by exotic grasses; however, higher TDN was recorded for the blue grama grass. Rhodes grass obtained the lowest ME at 80 dar (1.76), while the highest ME was obtained by buffel at 50 dar (1.91). The three varieties can be defoliated when the plants show intermediate yield and nutritional value, *i.e.*, 80 days after the regrowth begins; nevertheless, buffel and rhodes should be defoliated at 50 dar.

Keywords: forage grasses, *Bouteloua*, grasslands.

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INTRODUCTION

Natural grasslands cover less than 15% of the Chihuahuan Desert, approximately 5% of which is occupied by blue grama grass (*Bouteloua gracilis*) (Granados-Sánchez *et al.*, 2011). Buffel grass has spread throughout the whole Mexican Northeast; according to Gómez *et al.* (2007), 104,783 ha, 27,167 ha, and 600,000 ha were planted in Coahuila, Nuevo León,

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and Tamaulipas, respectively. Cattle are fond of buffel and other grasses from semi-arid areas; however, the cells of each plant of older regrowth grass have a limited access to nitrogen, cellulose, hemicellulose, and cell content, because lignin thickens the wall and, therefore, makes it less accessible to microbial enzymes (Abas *et al.*, 2005; Castillo-López and Domínguez-Ordoñez, 2019). The main determining tissue in the digestibility of the C_3 and C_4 grasses (*Poaceae*) is the abundance of mesophyll (Buxton and Redfearn, 1997). Meanwhile, according to Bernal-Flores *et al.* (2017), the greater aggregation of lignin inside oats gramaoccurs mainly in xylem, bundle sheath, and bundle sheath extension. This determines digestibility and, together with ammonium, limits the formation of volatile fatty acids and metabolic protein (Okoruwa and Igene, 2014). The relative feed value (RFV) is an index for the prediction and classification of the nutritional quality of forage, based on the combined analysis of expected animal consumption, quantity of forage, and dry matter digestibility (Amiri *et al.* 2012; Núñez *et al.*, 2014). Blue grama grass is one of the most widely distributed native mexican grasses in semi-arid of Mexico; buffel grass is the most widely spread species that has been introduced in northeastern Mexico; finally, rhodes grass is able to adapt to temperate semi-arid highlands environments. However, there is no nutritional and morphological composition information about their phenological stages. The objective of this research was to evaluate the morphological, chemical, and nutritional composition of defoliated blue grama, buffel, and rhodes grass at 50, 80, and 110 days after regrowth.

MATERIALS AND METHODS

The experiment was carried out in facilities of the Universidad Politécnica de Francisco I. Madero, Hidalgo, Municipality of Francisco I. Madero, Hidalgo, which is located at 2,017 masl, has a dry temperate climate, with an average annual temperature of 16 °C, and 550 mm of precipitation. The site has a Vertisol type soil with clayey texture (Granados-Sánchez *et al.*, 2001). The work was carried out from April 1 to November 9, 2019.

Plant materials and pasture management

The experimental seeds of buffel grass (var. Titan) and blue grama (var. Cecilia) —provided by INIFAP-San Luis— were cultivated in the spring-summer of 2016 productive cycle, while the seeds of rhodes grass (var. Bell) —purchased from a commercial establishment— were cultivated in the 2017 agricultural cycle. The three grass species were established in July 2017 with a density of 15 kg pure live seed (PLS) ha^{-1} in three areas of 3.5 × 1.5 m per grass. There were four strip irrigations with an irrigation capacity of 1 L h^{-1}, to which 40 mm m^{-2} were applied on April 1 and 20, as well as on May 3 and 20, 2019. No fertilizer was applied during the whole study period. The uniformization cut was made on July 17, 2019, 10 cm above the ground. The experimental cuts were made at 50, 80, and 110 days after the standardization cut (dar) in three random sites per variety. On each sampling date, grass was harvested with scissors at 10 cm above the ground and then divided into leaves, stems, inflorescences, and dead material. Later, each component was placed in previously labeled paper bags, which were placed in a forced air stove at 60 °C until they reached constant weight. A H-5851 Ohaus Scout scale was used to weigh the samples. Total forage production was the sum of all morphological components. Afterwards, the components were mixed and ground using a 400 Pulvex pulverizer mill (<1.0 mm) and placed in paper bags for subsequent bromatological analysis. The analysis was performed in triplicate by a certified laboratory (AgroLab de México SA de CV, Gómez Palacio, Durango), in order to obtain the following values: crude protein (CP, %), neutral detergent fiber (NDF; %), acid detergent fiber (ADF; %), total digestible nutrients (TDN; %), relative feed value (RFV), metabolizable energy (ME; Mcal kg feed^{-1}), net energy for maintenance (NE_m), net energy for lactation (NE_l) and net energy gain (NE_g).

The records of monthly temperature and precipitation (Figure 1) were obtained from a meteorological station located 3 km away from the experimental site. The experimental design was completely randomized with three repetitions. The results were analyzed with SAS Proc GLM (2009) and subject to the Tukey test (α=0.05).

RESULTS AND DISCUSSION

During the study, the average annual temperature was 18.5 °C, the annual precipitation was 395 mm, and no frost was recorded.

Forage production

The highest forage production was observed in rhodes at 110 dar (12,936 kg ha^{-1}; Table 1), followed by buffel and blue grama ($P<0.001$) at 50 and 80 dar. These results confirm that buffel and rhodes (grasses of African origin) outnumber native American grasses by 1.7 and 2.7 times, respectively, as reported by Ibarra *et al.* (2005).

Leaf:stem ratio

At 50 dar, the leaf:stem ratio (Table 1) was higher for Buffel (1.68; $P<0.01$), while it was similar between rhodes and blue grama ($P>0.05$). At 110 dar, blue grama grass had a better ratio (0.94; $P<0.01$) than the introduced grasses, and rhodes and buffel had a similar ratio ($P>0.05$). The leaf:stem ratio of African grasses drastically decreases in older regrowths, unlike blue grama; this characteristic of blue grama may also be related to its better nutritional value as the grass gets older. The forage pastures quality depends on the frequency and intensity of defoliation; therefore, the higher the leaves ratio, the higher the

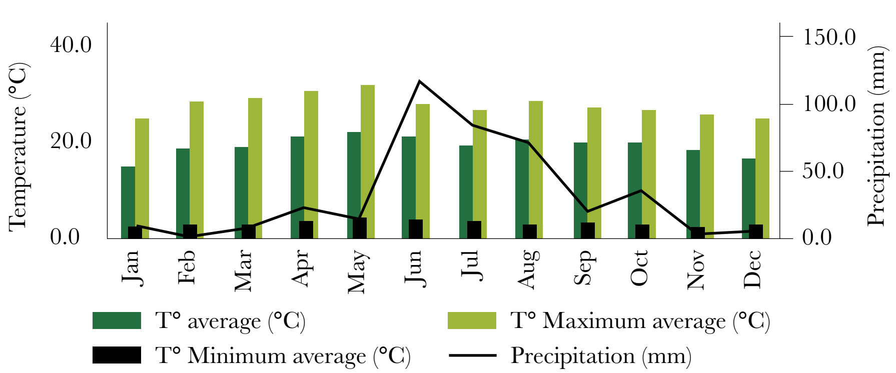

Figure 1. Annual temperature and precipitation 2019, in Francisco I. Madero, Hidalgo, Mexico.

Table 1. Morphological composition (g DM m^2) and forage production (kg DM ha^{-1}) established in Francisco I. Madero, Valle del Mezquital, Hidalgo, Mexico.

Grass name	dar	leaves	stems	infl	DM	sum	total (ha)	L:S
Rhodes	50	170^{a†}	146^{a}	20^{a}	5^{a}	357^{a}	8 923^{a}	1.16^{b}
Buffel		120^{b}	72^{b}	11^{b}	2^{b}	204^{b}	5 108^{b}	1.68^{a}
Blue grama		57^{c}	53^{b}	4^{b}	2^{b}	120^{b}	3 012^{b}	1.07^{b}
Average		116	90	12	3	224	225	1.3
Statistical significance		**	*	*	*	**	**	**
SEM		6.51	10.47	1.42	0.501	17.42	435	0.067
Rhodes	80	185^{a}	199^{a}	16^{a}	19^{a}	419^{a}	10 468^{a}	0.93^{b}
Buffel		148^{b}	104^{b}	17^{a}	5^{b}	273^{b}	6 833^{b}	1.42^{a}
Blue grama		72^{c}	76^{b}	9^{a}	3^{b}	160^{c}	3 999^{c}	0.95^{b}
Average		135	126	14	9	275	7 100	1.1
Statistical significance		**	**	NS	*	**	**	*
SEM		3.27	7.38	4.83	2.04	16.37	409	0.065
Rhodes	110	200^{a}	264^{a}	19^{a}	33^{a}	507^{a}	12 936^{a}	0.76^{b}
Buffel		154^{b}	207^{b}	27^{a}	15^{b}	300^{b}	10 263^{b}	0.74^{b}
Blue grama		84^{c}	90^{c}	12^{b}	4^{c}	189^{c}	4 719^{c}	0.94^{a}
Average		146	187	19	17	355	9 306	0.81
Statistical significance		**	**	**	**	**	**	**
SEM		3.16	5.53	1.36	1.44	7.25	182	0.02

† The same lowercase letters per column are statistically similar averages (P>0.05). dar=days after regrowth. DM=Dead Material. SEM=Standard error of the mean. *P<0.05, **P<0.01. NS=not significant differences (P>0.05).

forage quality (Lemaire *et al.*, 2009). Likewise, the higher the nutritional quality of forage, the higher the voluntary consumption by ruminants, as a result of the higher speed of passage in their gastrointestinal tract (Núñez *et al.*, 2014). Finally, a higher lignin ratio is observed at a higher rebound age: that is, ferulic acid is deposited in juvenile stages and p-coumaric acid is deposited throughout development (Casler and Hatfield, 2006).

Nutritional quality

For the three grass species studied, the older the plant, the lower the CP, TDN, RFV, ME, NE_l, NE_m, and NE_g (Table 2). In addition, NDF and ADF increased as the plants grew older, as reported by Bernal-Flores *et al.* (2017). The CP content in buffel grass at each cutting date was higher than in rhodes and blue grama (P<0.001). This is a key element in the management of grasslands, since it implies that more than 50% of the amino acids absorbed by ruminants ranges from 70 to 100% N. Likewise, it is important for the synthesis of microbial protein in the rumen and is used for growth, maintenance, and animal production (Rodríguez *et al.*, 2007; Das *et al.*, 2014). In the case of rhodes grass, CP decreased by 7% at 80 and 110 dar; this percentage is critical for the multiplication of microorganisms and therefore protein and metabolizable energy.

The forage pastures quality is given by the constitution of the epidermal tissues; therefore, in C_4 species such as the grasses included in this study, the mesophyll, phloem, epidermis,

Table 2. Chemical composition of rhodes, buffel, and blue grama grasses at three dates after regrowth in Francisco I. Madero, Valle del Mezquital, Hidalgo, Mexico.

Grass name	dar	CP (%)	NDF (%)	ADF (%)	TDN (%)	RFV (%)	Mcal kg^{-1}			
							ME	NE_l	NE_m	NE_g
Rhodes	50	$7.49^{c\,\dagger}$	74.42^{b}	45.17^{c}	53.09^{b}	66.20^{b}	1.87^{ab}	1.14	1.02^{a}	0.49
Buffel		10.7^{a}	69.5^{c}	46.55^{b}	52.9^{c}	70.4^{a}	1.91^{a}	1.17	1.13^{b}	0.52
Blue grama		8.03^{b}	78.59^{a}	49.0^{a}	56.50^{a}	60.10^{c}	1.85^{b}	1.13	1.05^{ab}	0.49
Average		8.73	74.18	46.91	54.17	65.57	1.88	1.15	1.07	0.50
Statistical significance		***	**	***	***	**	*	NS	*	NS
SEM		0.045	0.605	0.024	0.032	0.754	0.011	0.032	0.022	0.026
Rhodes	80	6.60^{c}	75.61^{b}	46.72^{c}	52.69^{b}	63.50^{b}	1.76	1.12	1.01	0.48
Buffel		9.30^{a}	70.46^{c}	47.98^{b}	52.89^{a}	67.60^{a}	1.86	1.15	1.04	0.51
Blue grama		7.85^{b}	79.45^{a}	51.15^{a}	52.90^{a}	56.50^{c}	1.84	1.11	1.01	0.46
Average		7.92	75.17	48.62	52.83	62.53	1.82	1.12	1.02	0.48
Statistical significance		***	***	***	**	***	NS	NS	NS	NS
SEM		0.031	0.311	0.033	0.026	0.613	0.023	0.023	0.024	0.016
Rhodes	110	6.38^{c}	75.30^{b}	48.33^{c}	51.02^{c}	64.40^{a}	1.88	1.07	0.96^{b}	0.42
Buffel		9.10^{a}	71.87^{c}	48.90^{b}	51.59^{b}	51.47^{c}	1.88	1.11	1.06^{a}	0.46
Blue grama		7.09^{b}	80.15^{a}	52.21^{a}	52.60^{a}	56.87^{b}	1.87	1.13	1.04^{ab}	0.48
Average		7.52	75.77	49.81	51.74	57.58	1.87	1.1	1.02	0.45
Statistical significance		***	***	***	***	***	NS	NS	*	NS
SEM		0.041	0.289	0.041	0.027	0.403	0.016	0.024	0.02	0.026

† The same lowercase letters per column are statistically similar averages ($P>0.05$). CP=Crude Protein. NDF=Neutral Detergent Fiber. ADF=Acid Detergent Fiber. TDN=Total Digestible Nutrients. RFV=Relative Feed Value. ME=Metabolizable Energy (Mcal kg^{-1}). NE_l=Net Energy of Lactation. NE_m=Net Energy of Maintenance. NE_g=Net Energy Gain. TDN=Total Digestible Nutrients. dar=days after regrowth. ***$P<0.001$, **$P<0.01$. SEM=Standard error of the mean, NS=no statistical significance ($P>0.05$).

parenchyma, and bundle sheath degrade slowly or partially (Guevara and Ramia, 2007). Therefore, in the case of the side oats grama (*B. curtipendula*), according to Bernal-Flores *et al.* (2017), the digestibility of the phloem and mesophyll is high and 70% of the chloroplast protein is concentrated in the latter. Meanwhile, xylem and sclerenchyma are high in lignin, especially in the primary veins, which consequently entails partial degradation. Blue grama grass had the highest TDN values in the three regrowth ages ($P<0.001$). This is a very positive output, because cattle cannot consume all the forage of the plots of a single ranch at one time. In the best of cases, ranchers organize certain sections for the dry season with physiologically mature plants. The grasses lose quality from pollination, as a consequence of the removal of soluble nutrients from leaves and especially from stems. These nutrients fill caryopses in inflorescences and therefore the lignin ratio increases (Li *et al.*, 2014). Buffel grass, like blue grama, showed a higher amount of TDN than rhodes ($P<0.01$) at 80 dar.

The influence of the nutrient digestibility percentage in the rumen results in a higher production of the following volatile fatty acids: acetate, propionate, and butyrate (Okoruwa and Igene, 2014). This increased production is reflected in a higher cattle productivity.

Therefore, the native blue grama grass will have a more positive effect on the ruminal microbiota: a greater production of metabolizable energy at a higher regrowth age. This can help to organize grazing in ranches in the Mexican deserts. That is, first defoliate introduced grasses and then native grasses. Therefore, to provide better pasture quality to ruminants in the natural grasslands of the Mexican deserts, ranchers will have to use grasses at 80 dar (2.5 months of regrowth), when forage production, CP, ME, and RFV are the most adequate. In the case of grasslands with rhodes and buffel grasses, grazing between 50 and 80 dar is recommended. The NDF and ADF percentages in the three grass species increased along with the age of the plants, as reported by Agnusdei *et al.* (2011). Meanwhile, blue grama grass showed higher NDF and ADF than rhodes and buffel grass ($P<0.001$); however, it also had a higher digestibility (TDN; $P<0.001$).

Overall, the highest RFV were recorded with younger plants: buffel grass stood out at 50 ($P<0.01$) and 80 ($P<0.001$) dar, while rhodes grass at 110 dar obtained better results ($P<0.001$). However, the TDN of blue grama grass was greater at 110 dar, although this is not reflected in the RFV, as a result of the higher DM production in rhodes and buffel. This production is related with the matrix that obtains the relative value of forage. Differences ($P<0.01$) in metabolizable energy were observed only at 50 dar. The metabolizable energy is given by the digestibility and concentration of protein, fat, non-fibrous, and fibrous carbohydrates in the forage (Weiss, 1996). Meanwhile, the energy content of forages is given mainly by the content, type, and digestibility of carbohydrates (Núñez, 2014); which affects the dry matter intake of cattle.

CONCLUSIONS

The introduced buffel and rhodes grasses surpassed blue grama grass by 1.7 and 2.7 times in forage production, respectively; however, blue grama grass had a consistent leaf:stem ratio. Buffel grass had a higher crude protein and relative value of forage, while rhodes grass produced a greater amount. Out of the three grass species, buffel and rhoes had the best pasture quality at 80 dar and 50 dar, respectively. On its turn, the total digestible nutrients in blue grama grass were higher in the most senescent stage.

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