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FORAGE CHARACTERIZATION OF BUFFEL-GRASS (*Cenchrus ciliare* L.) IN SEMI-DRY TO SEMI-WARM CLIMATES IN ZACATECAS, MEXICO

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ABSTRACT

Buffel grass (*Cenchrus ciliare* L.) is a species used for the production of forage that is characterized by its adequate adaptation to diverse environments. The aim was to evaluate the characteristics of forage and seeds from four materials and a variety of Buffel grass under rainfed conditions in the semi-dry and semi-warm weather of Zacatecas. The experiment was held in Huanusco, Zacatecas, Mexico, in a totally randomized block design with three replications. The materials were: M-42, M-45, M-66, M-S245, and the Titán variety as a control. For forage, two cuts were performed, considering the variables of plant height (PH), production of dry matter (DM), crude protein (CP), and *in vitro* digestibility of dry matter (IVDDM). Seed characteristics were determined upon physiological maturity using the variables of seed yield (SY), number of spikes per plant (Sp/plt), caryopsides per spikelet (Car/sp), and area of caryopsides (Area/Car). The data were analyzed in SAS, and the means were compared using Lsmeans. For the variable PH, M-42 stood out with an average height of 97.3 cm. In the production of DM, M-42 and M-45 surpassed Titán ($p < 0.05$), with yields higher than 4.4 Mg ha^{-1}. M-42 had the greatest CP content at 7.29 %, whereas M-45 and M-S245 had the highest IVDDM concentrations at 74.5 and 74.8 %, respectively. Regarding seed characteristics, M-42 surpassed Titán, with a SY of 295 kg ha^{-1}. The study concluded that M-42 is the best option for grassland management in Zacatecas, Mexico, where the weather is semi-warm and semi-dry.

Keywords: digestibility, seed, caryopsis, protein.

INTRODUCTION

Rainfed prairies are a source of high-quality forage for animal production systems. In addition to serving as a source of food for cattle, grasslands also reduce production costs for livestock farmers. They act as carbon sinks that contribute to the mitigation of climate change and promote agricultural and cattle sustainability. Grasslands in Mexico are constantly deteriorating due to overgrazing. Unfortunately, the renewal rate is no higher than 5 % (Enríquez-Quiroz *et al*., 2021). In order to counteract this problem, planting species adapted to the region of interest is recommended. Buffel grass (*Cenchrus ciliare* L.) is recommended for the establishment and management in grasslands due to its broad adaptation to climates and diverse soils (Rajora *et al*., 2021). In arid and temperate climates in Mexico where the average rainfall is between 298 and 550 mm, Buffel grass surpassed native species such as Sideoats Grama (*Bouteloua curtipendula*) and Blue Grama (*Bouteloua gracilis*), and even other African grasses such as Saw-tooth Love grass (*Eragrostis superva*), Weeping Love grass (*Eragrostis curvula*), and Kleingrass (*Panicum coloratum*) in dry matter production (Terrazas and Chávez, 2012a; Álvarez-Vázquez *et al*., 2022). In recent years, the National Research Institute for Livestock, Agriculture, and Forestry (INIFAP) evaluated a collection of Buffel grass in Mexico composed of 17 materials and two varieties (Formidable and T-4464). Out of these materials, four stood out in the production of forage and seeds (Terrazas and Chávez, 2012a; Terrazas and Chávez, 2012b). In a study that evaluated a collection of 126 ecotypes in Africa, values ranging from 1302 to 7442 kg MS ha^{-1} were reported (Sánchez-Gutiérrez *et al*., 2017), which sustains the need to evaluate materials in the same species to give pertinent recommendations for their use.

In Zacatecas, Mexico, there is an optimal and suboptimal potential area for Buffel grass of 96 624 and 2 693 005 ha, respectively (Medina *et al*., 2001). However, to date, the forage characteristics of the outstanding INIFAP materials, which may be a better forage alternative for the semi-dry and semi-warm Zacatecas climate, are unknown. Therefore, the aim of this study was to evaluate the forage and seed characteristics of four materials and one variety of Buffel grass under rainfed conditions in the semi-dry and semi-warm climate of Huanusco, Zacatecas, Mexico, to provide a recommendation for planting material.

MATERIALS AND METHODS

Study area

The experiment was conducted at the National Research Institute for Livestock, Agricultural, and Forestry (INIFAP), Los Cañones Experimental Station, located in the municipal area of Huanusco, Zacatecas, Mexico (102° 58’ W and 21° 44’ N), at an altitude of 1508 m. The soil is loamy, with a pH of 8.2 and a depth of over 1.5 m. The climate is semi-dry and semi-warm, with an annual average temperature of 29 °C and an average annual rainfall of 582 mm, with rains concentrating between June and September (Medina and Ruíz, 2004) (Figure 1).

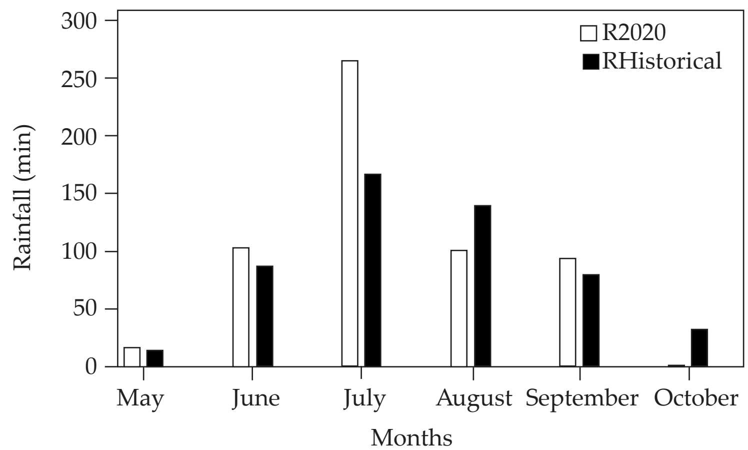

Figure 1. Monthly rainfall (mm) at Los Cañones Experimental Station in Huanusco, Zacatecas, Mexico, for 2020 (R2020) and the historical average (Rhistorical) (INIFAP Weather Station).

Design and experimental unit

The experiment was established in 2019 under a totally randomized experimental block design with three repetitions. Each block was established perpendicular to the slope, grafting plants manually. The materials evaluated were as follows: 1) M-42, 2) M-45, 3) M-66, 4) M-S245, and the Titán variety as a control. The experimental unit consisted of five rows, each 0.76 m wide and 15 m long. A distance of 0.75 m was set between plants. For the useful plot, 6 m were used in three central furrows, for a total of 18 plants.

Agronomical and bromatological analysis of the forage

The study began on May 12, 2020, with a standardization cut 5 cm above the ground level. To estimate the forage production, two cuts were made, one 45 days after the first rainfall (15 mm) and another 45 days later. The variables considered were: plant height (PH), dry matter production (DM), crude protein (CP), and *in vitro* digestibility of dry matter (IVDDM). For PH, a wooden ruler was used, and the measurement was taken from the base of the crown to the highest point of the forage or inflorescence. To estimate DM production, the useful plot was cut and the fresh forage was weighed. Later, a sample (500 g) was taken and placed in a forced air oven at 55 °C for 72 hours. The dry sample was then weighed, and the DM content was determined. The DM percentage was multiplied by the fresh weight of the plot, and the dry weight per hectare was extrapolated. Later, the samples were ground in a Willy mill with a 1 mm sieve.

The DUMAS method was used to determine the CP. The samples were processed with the LECO® FP-528 DSP equipment (Leco Instruments; Geleen, Netherlands). For the IVDDM, 0.5 g of sample were used in duplicate and stored in F57 bags. In addition to the blank (without forage), alfalfa and stubble samples were taken as references. The ruminal liquid was collected from calves with high-forage diets that were sacrificed in the municipal butchery. Finally, the procedures recommended by the manufacturer were followed using a Daisy incubator (ANKOM Technology; Macedon, NY, USA). All variables were determined in each cut. For DM production, the sum of the forage was recorded, and for the remaining variables, the means were considered.

Analysis of the seed

Seed characteristics were determined when they reached physiological maturity. The variables considered were: seed yield (SY), number of spikes per plant (Sp/plt), caryopsides per spikelet (Car/sp), and area of caryopsides (Area/Car). For SY, the seed was harvested by hand from the useful plot. In addition, four plants were chosen at random to count Sp/plt. Later, eight spikes were taken, and the caryopsides were extracted (Car/sp) by hand. To measure the Area/Car, 25 caryopsides were taken and observed in a Labomed CZM6 stereoscope (Labomed Inc.; Los Angeles, CA, USA).

Statistical analysis

Before the statistical analysis, the data underwent a normality test with Shapiro-Wilks and Bartlett tests for the homogeneity of variances. In both tests, normality and homogeneity were assumed, as long as they displayed a value of $p > 0.05$. Finally, the data were analyzed with "PROC GLM" of the SAS statistical package with a random block analysis. The means were compared using Lsmeans and were separated at a probability of less than 5 % (SAS, 2011).

RESULTS AND DISCUSSION

The total rainfall in this investigation during the crop cycle was 525 mm. The highest rainfall concentration was recorded between June and September (Figure 1). The materials presented differences ($p < 0.05$) in all the forage attributes evaluated. In PH, M-42 stood out, obtaining values higher than the control. The highest yields in the production of DM were obtained in M-42 and M-45, outperforming the control. For CP, the highest concentration ($p < 0.05$) was obtained in M-42, while the rest did not surpass 6 %. The highest IVDDM was found in M-45 and M-S245 with values of over 74 %, surpassing ($p < 0.05$) Titán (Table 1).

The weather conditions in this study were favorable for the materials since Titán presented a higher yield in comparison to other studies, in which DM production was 2370 kg ha^{-1} with 368 mm of rainfall (Beltrán-López *et al*., 2017). Additionally, the DM yields of all materials are within the ranges reported in the literature. Materials M-42 and M-45 are the best alternatives for the semi-dry and semi-warm climate of Zacatecas, resulting in a DM increase from 650 to 960 kg ha^{-1} more than Titán. This would represent over 62 thousand Mg of annual forage for the high-potential region of Zacatecas.

Table 1. Forage characteristics of five Buffel grass (*Cenchrus ciliare* L.) materials evaluated in Los Cañones Experimental Station, Huanusco, Zacatecas, Mexico, under rainfed conditions.

Material	PH (cm)	DM (kg ha^{-1})	CP (%)	IVDDM (%)
M-42	97.3 a	4771.1 a	7.29 a	73.19 b
M-45	80.3 b	4461.5 a	5.89 b	74.48 a
M-66	88.87 ab	3382.8 c	5.81 b	72.66 b
M-S245	80.61 ab	4411.96 ab	5.33 b	74.79 a
Titán (control)	84.89 ab	3811.2 bc	5.88 b	72.84 b
R^2	0.66	0.82	0.73	0.82
C.V.	10.7	10.2	9.26	9.2

PH: plant height; DM: dry matter; CP: crude protein; IVDDM: *in vitro* digestibility of dry matter; R^2: coefficient of determination; C.V.: coefficient of variation. Different letters between columns indicate significant differences ($p < 0.05$).

On the other hand, the mean value of CP in Titán (5.88 %) is similar to the 6.1 % reported in the flowering stage by Beltrán-López *et al*. (2017). M-42 represents an alternative to lower feed costs for CP supplementation since it outperformed Titán by 1.4 %. According to studies in forage genetic breeding, every unit increase in IVDDM results in a 3.2 % increase in daily yield per head (Casler and Vogel, 1999). M-45 could improve animal performance by increasing IVDDM by 2.25 % as compared to the control.

All seed characteristics varied across materials. M-42 had the largest seed production (75 % higher than Titán), although it was statistically similar ($p < 0.05$) to M-45 and M-66 yields. For spikelets per plant, M-42 presented a value 113 % higher than the control variety, but equal to the value for M-45. M-42 outperformed the control in Car/sp and Area/Car by 146 and 62 %, respectively (Table 2).

Table 2. Characteristics of seeds in five Buffel grass (*Cenchrus ciliare* L.) materials evaluated in Los Cañones Experimenal Station, Huanusco, Zacatecas, Mexico, under rainfed conditions.

Material	SY (kg ha^{-1})	Sp/plt	Car/sp	Area/Car (mm^{-2})
M-42	295.19 a	77 a	64 a	3.13 a
M-45	179.7 ab	51 ab	17 b	2.07 b
M-66	184.1 ab	26 b	14 b	1.8 b
M-S245	170.8 b	32 b	15 b	2.38 b
Titán (control)	140.9 b	36 b	26 b	1.93 b
R^2	0.72	0.72	0.67	0.73
C.V.	33.7	36.8	65	17.6

SY: seed yield; Sp/plt: spikelets per plant; Car/sp: caryopsides per spikelet; Area/Car: area of caryopsides; R^2: coefficient of determination; C.V.: coefficient of variation. Different letters within columns indicate significant differences ($p < 0.05$).

Seed production is similar to that of the outstanding genotypes in a collection of Buffel grass evaluated in Colombia, where the rainfall is over 1500 mm, finding a value of over 210 kg ha^{-1} (Erazo *et al*., 2022). In addition, the means presented for both Sp/plt and Car/sp are within the range reported in the 157 materials evaluated in Ethiopia (Sánchez-Gutiérrez *et al*., 2020). The results with M-42 are higher than those reported in the varieties Común, Nueces, and Formidable, since Conde-Lozano *et al*. (2011) mention that the value of Sp/plt did not surpass 33, and for Car/sp, it was lower than 39. Hernández-Guzmán *et al*. (2021) concluded that the larger the caryopsides, the greater the increase in biomass production in Buffel and Rhodes grasses. Due to the above, M-42 is proposed as an option in arid climates like the one used in this study to restore regions where forage is in decline. Since M-42's caryopsides are larger, it is also anticipated that the establishment's success will increase.

CONCLUSIONS

When compared to the control (Titán), material M-42 had the highest protein concentration, the highest production of dry matter, and better seed characteristics. These attributes make it a viable and nutritious choice, particularly when forage area recovery is required since the expected establishment of this grass would be more significant. On the other hand, M-45 produces more dry fodder and has higher digestibility rates than Titán, making it suitable for use in the research area's meteorological conditions. As a result, materials M42 and M-45 are viable options for grassland rehabilitation and management programs in the Zacatecas' semi-warm and semi-dry climates.

REFERENCES

Álvarez-Vásquez P, Rojas-García AR, Joaquín-Cancino S, Velázquez-Martínez M, Rodríguez-Ortega LT, Hernández-Guzmán FJ. 2022. Producción de forraje y semilla de ocho pastos al establecimiento en Tulancingo, Hidalgo. Revista Mexicana de Ciencias Agrícolas 13 (6): 1041–1053. https://doi.org/10.29312/remexca.v13i6.3027

Beltrán-López S, García-Díaz CA, Loredo-Osti C, Urrutia-Morales J, Hernández-Alatorre JA, Gámez-Vázquez HG. 2017. "Titán" y "Regio", variedades de pasto Buffel (*Penisetum ciliare*) (L.). Link para zonas áridas y semiáridas. Revista Mexicana de Ciencias Pecuarias 8 (3): 291–295. https://doi.org/10.22319/rmcp.v8i3.4159

Casler MD, Vogel KP. 1999. Accomplishments and impact from breeding for increased forage nutritional value. Crop Science 39 (1): 12–20. https://doi.org/10.2135/cropsci1999.0011183x003900010003x

Conde-Lozano E, Martínez-González JC, Briones-Encinia F, Saldivar-Fitzmaurice AJ. 2011. Producción de semilla de pasto Buffel (*Cenchrus ciliaris* L.) bajo diferentes ambientes agroecológicos en Tamaulipas, México. Revista de la Facultad de Agronomía de la Universidad del Zulia 28 (3): 360–375.

Erazo EB, Mojica-Rodríguez JE, Brochero-Aldana GA, Mejía-Salazar JR, Mejía-Kerguelen L, Burghi VH. 2022. Variation in floral morphology and seed production of Buffel and Rhodes grass. Journal of Agricultural Science and Technology 24 (2): 155–168.

Enríquez-Quiroz JF, Esqueda-Esquivel VA, Martínez-Méndez D. 2021. Rehabilitación de praderas degradadas en el trópico de México. Revista Mexicana de Ciencias Pecuarias 12: 243–260. https://doi.org/10.22319/rmcp.v12s3.5876

Hernández-Guzmán FJ, Rodríguez-Ortega LT, Velázquez-Martínez M, Landa-Salgado P, Rodríguez-Ortega A, Castrellón-Montelongo JL. 2021. Influencia del tamaño de cariópside y embrión en el desarrollo de plántulas de pastos. Interciencia 6 (7–8): 309–316.

Medina GG, Salinas GH, Rubio AF. 2001. Potencial productivo de especies forrajeras en el Estado de Zacatecas, libro técnico 1. Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias. Centro de Investigación Regional Norte Centro, Campo Experimental Zacatecas. Calera, México. 157 p.

Medina GG, Ruiz CA. 2004. Estadísticas climatológicas básicas del Estado de Zacatecas. Libro técnico 3. Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias. Centro de Investigación Regional Norte Centro, Campo Experimental Zacatecas. Calera, México, pp: 40–41.

Rajora MP, Jadon KS, Roy PK, Patidar M, Bhatt RK. 2021. Forage yield performance of five elite genotypes of Buffel grass in hot arid region of Rajasthan. Range Management and Agroforestry 42 (2): 198–204.

Sánchez-Gutiérrez RA, Morales-Nieto CR, Hanson J, Santellano-Estrada E, Jurado-Guerra P, Villanueva-Avalos JF, Melgoza-Castillo A. 2017. Caracterización forrajera de ecotipos de zacate Buffel en condiciones de temporal en Debre Zeit, Etiopía. Revista Mexicana de Ciencias Agrícolas 8 (1): 13–24. https://doi.org/10.29312/remexca.v8i1.68

Sánchez-Gutiérrez RA, Hanson J, Jones C, Jurado-Guerra P, Santellano-Estrada E, Melgoza-Castillo A, Morales-Nieto C. 2020. Caracterización morfológica de genotipos de pasto Buffel con potencial para la producción de forraje y semilla. Revista Fitotecnia Mexicana 43 (3): 343–347. https://doi.org/10.35196/rfm.2020.3.343

SAS Institute. 2011. SAS/STAT 9.3 User´s Guide. SAS Institute Inc. Cary, North Carolina, USA.

Terrazas PJG, Chávez MC. 2012a. Rendimiento y calidad de forraje de materiales sobresalientes de zacate Buffel *Cenchrus ciliaris* en cinco estadios de crecimiento. *In* Baez IF. (ed.), Resultados de Investigación sobre Zacate Buffel *Cenchrus ciliaris* de Temporal en la Región Centro de Chihuahua. Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias, Campo Experimental Delicias: Delicias, México, pp: 21–38.

Terrazas PJG, Chávez MC. 2012b. Rendimiento y calidad de semilla de materiales sobresalientes de zacate Buffel *Cenchrus ciliaris* en condiciones de temporal en la zona centro sur de Chihuahua. *In* Baez IF. (ed.), Resultados de Investigación sobre Zacate Buffel *Cenchrus ciliaris* de Temporal en la Región Centro de Chihuahua. Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias, Campo Experimental Delicias: Delicias, México, pp: 39–49.