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# Agronomic attributes and forage production in ecotypes of *Cenchrus purpureus* under subhumid tropical conditions

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## Abstract

The morphology and forage production were studied in 16 ecotypes of *Cenchrus purpureus* (Schumach.) Morrone, under subtropical conditions of the state of Nayarit, Mexico. The study was conducted at the El Verdineño-INIFAP Experimental Site. The materials evaluated included: Elephant, Uruguana, Taiwan, CT-169, Caña Africana, Maralfalfa, Mott, Roxo, purple King grass, CT-115, Merkeron, Cameroon, green King grass and three ecotypes from Tamaulipas: Elephant Tamps, Maralfalfa Tamps and Roxo Tamps, established in plots of 2 x 4 $m^2$, with three furrows of six plants each, at a rate of 25 000 plants $ha^{-1}$. The evaluations were conducted during the period of water deficit (January-July) of 2019 at 180 days of regrowth. Morphological variables included: plant height, stem density per crown, basal and central stem diameter, width and length of the central leaf blade, number of internodes and central internode length. For production, they included: dry matter (DM) production, absolute growth rate and leaf:stem ratio. Data were analyzed using a completely randomized design, including the 16 ecotypes, and comparison of means with Tukey ($p< 0.05$). In all materials, significant differences ($p< 0.01$) were observed between morphological and productive variables. The outstanding materials for DM production were Elephant Tamps and Caña Africana, with a production of 60.9 and 57.3 Mg DM $ha^{-1}$; likewise, for absolute growth rate: 338.5 and 318.5 kg DM $ha^{-1}$ $day^{-1}$. These ecotypes constitute an excellent alternative for their use in the different beef and milk production systems in the tropical areas of Mexico; the above, under a cut at 180 days of regrowth in the dry season.

**Keywords:** *Cenchrus purpureus*, forage production, morphology.

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# Introduction

*Cenchrus purpureus* [Schumach.] Morrone has subtropical Africa as its center of origin (Singh *et al*., 2013). It is a species with $C_4$ photosynthesis, of rapid growth, grows well in tropical climatic conditions and soils with good moisture retention (De Morais *et al*., 2012). Recent studies on this species focus on topics such as ethanol production, cellulose for paper, direct combustion of biomass, substitute for charcoal and as forage for animal feed (Rueda *et al*., 2016).

This is one of the most used forages by ruminants in tropical developing countries (Rahman *et al*., 2019). Its use in livestock production systems has increased as forage for cut, grazing and reserve forage for dry periods. Due to its high values in dry matter (DM) production, leaf ratio, rusticity and plasticity; which allow it to adapt to a great diversity of soil types (including those of low fertility) and adverse climatic conditions of high temperatures and low rainfall (García *et al*., 2018).

Forage canes respond to different productive approaches, based on three potential uses: 1) cutting or grazing with good forage quality, with use without the morphological expression of the elongation plant phase; the above with cuts/grazing at a maximum of 1 m of plant height; 2) silage or cutting, with low forage quality, with the presence of stems and use at 2 m of plant height, in combination with crops such as corn (silo) or packaged; and 3) for biomass (biofuel, bioenergy, cellulose for paper or fiber source for rumination promotion in concentrated feeds for pen feeding), with cuts at plant heights above 3-4 m.

*Cenchrus ciliaris* Syn. *Pennisetum purpureum* (Schum.) was introduced in Latin America at the beginning of the twentieth century (Oliveira *et al*., 2017). In the 1980s, the National Institute of Livestock Research (INIP, for its acronym in Spanish), now INIFAP, made the first studies in Mexico with the ecotypes Elephant and Merkeron (Quero *et al.*, 2018). Subsequently, materials from the Institute of Animal Science (ICA for its acronym in Spanish), Cuba, were introduced, being the cultivars King grass, CT-115 and CT-169, the latter two obtained by tissue culture (Herrera *et al*., 2012). Currently, it is one of the most widespread forage species in the tropical and subtropical regions of Mexico (Calzada *et al*., 2018).

However, it has been shown that it is also an option for forage production in the semiarid region, if irrigation is available (Ortiz *et al*., 2017). In Mexico, there are more than 20 ecotypes introduced and most of these are not well characterized based on morphology and forage production, this is because most studies have focused on 20% of existing materials and their use has come to cause confusion among producers.

The varieties and ecotypes of *C. purpureus* have morphological, physiological and productive advantages that make them desirable under specific edaphoclimatic conditions (Ramos *et al*., 2013), so, initially, a morphological characterization is required to know the diversity of the material, before its introduction and use in each agroecological region (Garduño *et al*., 2017; Vázquez and Gonzalez, 2017). Therefore, the objective of the study was to characterize the morphology and forage production of 16 ecotypes of *Cenchrus purpureus* (Schum.) Morrone, under subhumid tropic conditions ($Aw_2$) of the state of Nayarit, Mexico.

## Materials and methods

The study was carried out at the El Verdineño - INIFAP Experimental Site, in Santiago Ixcuintla, Nayarit, Mexico (21° 42' 9.60" north latitude and 105° 07' 5.58" west longitude), at 50 masl, warm subhumid climate ($Aw_2$), with rains in summer, average temperature of 22 °C and annual precipitation of 1 201 mm, clayey soil, slightly acidic pH, no presence of salinity, medium fertility and good drainage (Villanueva *et al*., 2021).

The treatments consisted of 16 ecotypes of *Cenchrus purpureus*: Elephant, Uruguana, Taiwan, CT-169, Caña Africana, Maralfalfa, Mott, Roxo, purple King Grass, CT-115, Merkeron, Cameroon, green King Grass. Three ecotypes from the Las Huastecas-INIFAP EF, Tamaulipas, were included: Elephant, Maralfalfa, Roxo (it is suspected that they are the same ecotypes already existing in the collection of genetic resources of the El Verdineño ES, so to the identification for data collection and be able to discriminate, these three materials were added the acronym Tamps to differentiate them from the existing ones in the experimental site).

All these are currently available in the Germplasm Bank of Forage Genetic Resources of the 'El Verdineño' ES. The experiment was established using vegetative material with cuttings, in July 2018 in the rainy season, plots of 2 x 4 $m^2$ were established, with three furrows of six plants each, with a density considered low, of 2.5 plants per $m^2$, at the rate of 25 000 plants per hectare (pl $ha^{-1}$). For the evaluation, four plants of the central furrow were used, eliminating the edges.

First, a homogenization cut was made, and the evaluations were conducted during the critical period of water deficit (January-July) of 2019 at 180 days of regrowth. The morphological variables evaluated included (Herrera, 2014): total plant height (HE), measured with the standing plant up to the naturally highest leaf using a 5 m Lufkin tape measure; stem density per crown (SDC), counting the total number of stems in the plant at the time of cutting; basal stem diameter (BSD) and central stem diameter (CSD), these two variables were measured in four stems per plant harvested using a digital vernier; central leaf blade width (CLBW); central leaf blade length (CLBL); central internode length (IL), measured with a tape measure; number of internodes per plant (NIP), by counting.

Production variables included: 1) dry matter (DM) production, four whole plants were selected and harvested in green, separating leaves and stems and they were weighed in a high-precision electronic balance with a capacity of 50 kg ±0.05 g; subsequently, a sample of 300 g of each component was taken and dried at a constant temperature of 60 °C, in a forced air oven, until reaching a constant weight (Herrera, 2014), from which the dry weight of the whole plant was estimated and the data were extrapolated to DM production per hectare; 2) absolute growth rate (AGR), using the formula AGR= DW/t. Where: DW= dry plant weight; and t= time of regrowth period (Hunt, 2003); and 3) leaf:stem ratio, using the quotient dry leaf weight: dry stem weight (Hernández *et al*., 2011; Liendo *et al*., 2019). For the statistical analysis, a completely randomized design with 16 treatments and four repetitions (plants) was used, and the Tukey test for comparison of means ($p< 0.05$); the above using the statistical package SAS, Version 9.0.

## Results and discussion

All cultivars expressed their maximum growth at 180 days of regrowth in the dry period. The CT-169 cultivar significantly exceeded ($p$< 0.01) the height reached compared to the other cultivars (Table 1). Rueda *et al*. (2016) report height values greater than 4 m in eight cultivars of *C. purpureus* at 185 days of regrowth in the dry period. These values are higher than those found in the present study, differences that are attributed to the different ecotypes and edaphoclimatic conditions. Similarly, it is worth mentioning that the dry seasons in conditions of dry tropics in this study are more severe than the dry season in the humid tropics, where worked Rueda *et al*. (2016).

**Table 1. Forage morphology in ecotypes of *Cenchrus purpureus*, evaluated in subtropical climate of the state of Nayarit, Mexico.**

| Cultivar | HE (m) | SDC | BSD (mm) | CSD (mm) | CLBW (cm) | CLBL (cm) | NIP | IL (cm) |
|---|---|---|---|---|---|---|---|---|
| Elephant Tamps | 2.74 abc | 19 ab | 21.5 ab | 20 a | 3.5 a | 94.5 abcd | 28 a | 9.25 abc |
| Uruguana | 2.95 ab | 13 cdef | 19.8 ab | 17.8 abc | 3.75 a | 104 a | 28 a | 14.7 a |
| Caña Africana | 2.81 abc | 18 ab | 18.8 ab | 17.8 abc | 3.13 ab | 87.8 bcd | 28 a | 11.7 ab |
| Taiwan | 2.74 abc | 16 bcde | 22.3 a | 17.8 abc | 3.75 a | 85.5 bcd | 26 ab | 12.3 ab |
| CT-169 | 3 a | 12 def | 19.5 ab | 17.3 abc | 3.38 ab | 98.5 abcd | 27 ab | 12.3 ab |
| Elephant | 2.8 abc | 11 def | 14.8 bc | 13.8 bc | 3.88 a | 80 cde | 26 ab | 8.38 bcd |
| Maralfalfa Tamps | 2.81 abc | 15 bcde | 18.5 ab | 13.8 bc | 2.88 ab | 79 de | 26 ab | 11 ab |
| Mott | 2.31 bcd | 21 a | 17.5 abc | 13.8 bc | 2.63 ab | 81.5 bcde | 21 abc | 10.8 ab |
| Maralfalfa | 2.49 abc | 19 ab | 22 ab | 19.8 a | 2.33 ab | 89.8 abcd | 26 ab | 12.7 ab |
| Roxo Tamps | 2.69 abc | 15 bcde | 18.8 ab | 17.3 abc | 3.63 a | 83 bcde | 26 ab | 7.88 bcd |
| Purple King Grass | 2.61 abc | 11 ef | 16 abc | 130 cd | 2.88 ab | 97.3 abcd | 28 a | 9.25 abc |
| CT-115 | 2.49 abc | 16 bcde | 17.3 abc | 16.3 abc | 2.63 ab | 91.8 abcd | 29 a | 8.88 abc |
| Merkeron | 2.58 abc | 8 f | 16.5 abc | 180 abc | 2.75 ab | 87.3 bcd | 25 ab | 7.13 bcd |
| Cameroon | 2.56 abc | 11 ef | 19.5 ab | 16.5 abc | 2.75 ab | 104 a | 17 bc | 10.8 ab |
| Green King Grass | 2.2 cd | 14 bcde | 10.3 c | 7.5 d | 1.75 b | 61 e | 17 bc | 13 ab |
| Roxo | 1.68 de | 18 abc | 19.8 ab | 19.3 ab | 3.25 ab | 76 de | 22 abc | 3.88 dc |
| MSD | ±1 | ±5.1 | ±7.2 | ±5.7 | ±1.7 | ±24.04 | ±10.38 | ±5.99 |

a, b, c= lowercase literals within the same column indicate differences ($p$< 0.01) between ecotypes. MSD= minimum significant difference; HE= plant height; SDC= stem density per plant; BSD= basal stem diameter; CSD= central stem diameter; CLBW= central leaf blade width; CLBL= central leaf blade length; NIP= number of internodes per plant; IL= internode length.

The Mott variety significantly exceeded ($p$< 0.01) the other cultivars in SDC; while the Taiwan variety was superior ($p$< 0.01) to all cultivars in BSD. Elephant Tamps and Maralfalfa were relatively superior ($p$< 0.01) in CSD (Table 1). Growth and stem production are the basic unit of production and persistence in grasses (Matthew and Sackville, 2011).

In smaller tilled grass species, a meadow in good conditions should contain between 50 000 and 60 000 mature crowns of desirable grasses per hectare, each producing 200 to 1 000 tillers during the active growing season (Quero *et al*., 2017). However, in *Cenchrus purpureus*, there is no defined number that results in less bare soil area in response to standardized management of cutting or grazing; therefore, it is very important to evaluate the behavior and production of the stems.

The ecotypes Elephant, Uruguana, Taiwan, Roxo Tamps and Elephant Tamps significantly exceeded ($p< 0.01$) the rest of the materials in CLBW. While Cameroon and Uruguana were significantly superior ($p< 0.01$) in CLBL. CT-115, Elephant Tamps, Uruguana, Caña Africana and purple King grass were significantly higher ($p< 0.01$) with respect to NI and for IL, only Uruguana was higher ($p< 0.01$) with respect to the remaining materials (Table 1).

Ecotypes that show greater numbers of internodes show an important competitive advantage, since they will have a greater number of leaves, which, associated with the length, thickness and width of the leaf, constitute the most valuable attribute for forage production (Carvalho *et al*., 2005). In a study with ecotypes of *Cenchrus purpureus*, Ledea *et al*. (2018a) point out that, in this species, the largest dimensions in stem thickness, internode length, length and width of leaf are reached at 120 days of regrowth.

Regarding the results obtained in forage production, the cultivars Elephant Tamps and Caña Africana showed significant differences ($p< 0.01$) with respect to the other varieties evaluated, with the highest values in DM production and Absolute Growth Rate (Table 2). High values in DM production are associated with AGR; however, it should be considered that a sustained increase in AGR should not always be interpreted as positive, since one of the particularities of tropical grasses is the accumulation of biomass and accelerated maturation of tissues; the above due to the wide capacity of assimilation of radiation that they have, which brings with it a chemical impact due to modifications of the cell wall with the consequent loss of nutritional value (Ledea *et al*., 2018b).

Several studies have been carried out with new ecotypes and clones of *Cenchrus purpureus* in different regions of Mexico: Rueda *et al*. (2016), with Taiwan, CT-115, OM-22 and Roxo; López *et al*. (2020), with Maralfalfa; Vázquez and González (2017); Calzada *et al*. (2018) with Taiwan. It has been concluded that the yield and nutritional quality of forage are influenced by the ecotype, environment and agronomic management (Arias *et al*., 2018; Caballero *et al*., 2016). However, forage yields in *Cenchrus purpureus* can also be increased by nitrogen fertilization (Da Silva *et al*., 2015).

For the leaf:stem ratio, Maralfalfa Tamps and CT-169 showed significant differences ($p< 0.01$), compared to the rest of the ecotypes evaluated, while Roxo and Roxo Tamps had the lowest values in L:S (Table 2). In studies with different forage species, it has been considered that the selection in high stem yield is an effective method to increase forage yield, but, when the number of leaves decrease, the quality, digestibility and protein content of the plant decreases (Volenec *et al*., 1987; Ledea *et al*., 2021).

**Table 2. Forage production in ecotypes of *Cenchrus purpureus*, evaluated in a subtropical climate of the state of Nayarit, Mexico.**

| Cultivar | DM (Mg $ha^{-1}$) | AGR (kg DM $ha^{-1}$ $day^{-1}$) | Ratio (leaf:stem) |
|---|---|---|---|
| Elephant Tamps | 60.9 a | 338.5 a | 1.49 abcd |
| Uruguana | 40.8 c | 226.7 c | 1.63 abc |
| Caña Africana | 57.3 a | 318.5 a | 1.85 ab |
| Taiwan | 46.2 b | 256.8 b | 1.39 cd |
| CT-169 | 32.6 d | 181.2 d | 1.89 a |
| Elephant | 17.6 he | 97.99 he | 1.43 bcd |
| Maralfalfa Tamps | 24 fg | 133.3 fg | 1.92 a |
| Mott | 25.6 fg | 142.2 fg | 1.14 of |
| Maralfalfa | 50.2 b | 279.1 b | 1.45 bcd |
| Roxo Tamps | 27.2 if | 151 if | 0.92 if |
| Purple King Grass | 16 jk | 88.6 jk | 1.28 cde |
| CT-115 | 31.7 of | 175.9 of | 1.53 abcd |
| Merkeron | 20.8 ghi | 115.7 ghi | 1.84 ab |
| Cameroon | 17.3 ij | 95.9 ij | 1.32 cde |
| Green King Grass | 11.5 k | 63.65 k | 1.25 cde |
| Roxo | 25.2 fg | 140 fg | 0.65 f |
| MSD | ±4.8 | ±26.6 | ±0.43 |

a, b, c= lowercase literals within the same column indicate differences ($p$< 0.01) between ecotypes. MSD= minimum significant difference; DM= dry matter yield; AGR= absolute growth rate.

Low values in the L:S ratio is associated with higher growth rates, causing an accelerated tissue replacement and greater contribution of the stem to the leaf/stem ratio (Luna *et al*., 2018). Araya and Boschini (2005) establish that forage species with a higher proportion of green leaves have higher protein content and better nutritional quality.

The leaves, which fulfill the function of synthesis and translocation of carbohydrates, have a high volume of parenchymal tissue located in the mesophyll; the above helps a better accumulation of proteins and non-structural carbohydrates that define their high nutritional values; the stems, on the other hand, have a large amount of vascular and supporting tissue, so their average nutritional value is significantly lower than that of the leaves and depends a lot on the content and type of structural carbohydrates they have.

The combination of high DM yield with a high leaf:stem ratio makes Caña Africana the best choice for forage as a source of fiber at this cut height; this is because, in DM yield, it far exceeds statistically similar materials in the leaf:stem ratio, such as CT-169 and Maralfalfa Tamps. When a higher leaf production is of interest at this plant height, Caña Africana is the best option. However, Ledea *et al*. (2021) mention that, in *Cenchrus purpureus*, both leaves and the whole plant show effects on the mineral profile (Ca and P) and protein content that do not allow excellent nutrition in ruminants; therefore, alternatives for forage supplementation should be considered when choosing to use some of these materials.

The use of the correct variety is an important practice to obtain the desired advantages, and in this case, the forage morphology is the main indicator for a correct selection of the material to be used in cattle ranches. Forage genetic resources represent an essential component of agricultural and livestock production value chains and in-depth knowledge of these available forage resources is required (Negawo *et al*., 2017).

## Conclusions

The forage morphology in *Cenchrus purpureus* shows significant variations between ecotypes and varieties, observing the existence of materials with outstanding forage attributes at the height evaluated: Length and width of leaf, number of internodes, among others, which make them excellent alternatives for their use and exploitation in the livestock systems of the tropical regions of Mexico. The morphological variables evaluated are discriminant for the identification of ecotypes of *Cenchrus purpureus*.

The dry matter production is very variable between different ecotypes and the best DM yields and absolute growth rate occurred in Elephant Tamps and Caña Africana, outstanding materials that constitute an excellent alternative for their use (cutting, hauling, silage and grazing), in this case, a single cut at 180 days of regrowth and for the different production systems in tropical areas of Mexico.

It is suggested to strengthen these results with grazing, agronomic and multilocational studies and evaluated at the plant height of interest for the intended use of biomass: 1) high quality: cutting/grazing/silage (1 m); 2) medium quality: silage (2 m); and 3) low quality: fiber (paper or rumination stimulant in the use of concentrated in pen and biofuel (between 3-4 m).

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