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Colegio de Postgraduados

Dry matter distribution of banderita grass [*Bouteloua curtipendula* (Michx.) Torr.] at different plant strata

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ABSTRACT
Objective: To evaluate the dry matter distribution of banderita grass [*Bouteloua curtipendula* (Michx.) Torr.] in different plant strata.
Design/Methodology/Approach: A randomized block experimental design with five repetitions was used for the experiment. Each repetition consisted of three plants which were evaluated at different days after sowing (DAS), in three different plant strata: basal stratum (BS), middle stratum (MS), and upper or apical stratum (AS). The following variables were evaluated: dry matter yield (DMY), morphological composition (MC), leaf area (LA), plant height (PH), leaf:stem ratio (L:SR), and aerial part:root ratio (Ap:rR). An analysis of variance was performed, using the PROC GLM procedure of the SAS software; in addition, a comparison of means was carried out using Tukey's test ($\alpha<0.05$).
Results: SB made a greater contribution to DMY at 50 DAS, with a 16 g DMY plant^{-1} average, followed by MS, with 9 g DM plant^{-1}, and AS with 3 g plant^{-1}. The MC (g) in the BS registered that the stem made a greater contribution than the rest of the components (average: 12.3 g plant^{-1}), while leaves from the MS and AS made the greatest contribution (2.6 g plant^{-1}) up to 64 DAS. However, they were surpassed by the stem in the MS and by the inflorescence in the AS. In addition, BS registered the highest LA (173.4 cm2). The largest PH was recorded at 120 DAS (96 cm). The highest L:SR ratio reached 1.10 at 50 DAS, while Ap:rR recorded 3.82 at 92 DAS.
Study Limitations/Implications: The experiment was carried out under greenhouse conditions. Therefore, any extrapolation or comparison with field conditions should be done with caution.
Findings/Conclusions: The basal and middle part of a *banderita* grass (*Bouteloua curtipendula*) plant contains the highest forage accumulation (mainly in the leaves and the stem), while the highest biomass content in the apical part is produced by the inflorescence.

Keywords: Native grass, leaf area, morphological composition, plant strata.

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INTRODUCTION

Most of the grasses in the arid and semi-arid areas of Mexico have deteriorated and produce little and bad quality forage (Guerra *et al.*, 2006); consequently, cattle producers face difficulties regarding the availability of forage, because its production depends on the edaphoclimatic and climatic conditions of the area where it is grown (Suttie, 2003) and developed (FIRCO, 2010). Therefore, determining different foraging alternatives —which have a higher tolerance to seasonal extreme temperatures in northern Mexico— is important. Several foraging species have qualities that complement the diet of cattle. Some of these plants belong to genus *Bouteloua*, which includes approximately 60 species, with a wide genetic variability and that are mainly distributed in northern Mexico (Peterson *et al.*, 2015). *Banderita* grass [*Bouteloua curtipendula* (Michx.) Torr] is native to Mexico, grows in plains and rocky low hills, and has an excellent foraging value for extensive grazing (Morales-Nieto *et al.*, 2016). *Banderita* grass produces plenty of forage, adapts to different climatic conditions, and is tolerant to drought; therefore, it is considered the second most agronomically important species within its genus (Morales-Nieto *et al.*, 2008). Its plants can grow to >75 cm tall and have 50-70% digestibility values (Corrales *et al.*, 2016). The forage yield depends on the phenological state of the plant. Additionally, it keeps its foraging value longer than other grasses (Morales-Nieto *et al.*, 2006). The annual average forage yield of *banderita* ranges from 1,850 to 2,000 kg DM ha^{-1}, with annual precipitations of 350-500 mm (Beltrán *et al.*, 2013). Consequently, the use of this high-value foraging species is an alternative for cattle raising, because it can help the economy of producers from the northern region of the country, increasing grazing in arid and semi-arid regions. Therefore, the objective of this study was to evaluate the dry matter distribution of *banderita* grass, in three plant strata (basal, middle, and upper or apical), at different days after sowing, during the spring-summer growing cycle.

MATERIALS AND METHODS

Study area description

The crops were established on April 25, 2022, in the greenhouse of the Departamento de Recursos Naturales Renovables, Universidad Autónoma Agraria Antonio Narro (UAAAN), Unidad Saltillo, located in southeastern Coahuila (25° 35’ 35” N and 101° 03’ 60” W, at 1,783 m.a.s.l.). The spring-summer growing cycle (April-August 2022) was evaluated. Maximum, minimum, and mean temperature, as well as relative humidity, was recorded using a FCCERoHS WS08 digital hygrometer.

Experiment establishment and experimental design

B. curtipendula var. NdeM-303 was used for a completely random block design, with five repetitions. Forty 8-kg plastic pots were established as experimental units (EU), using a previously sterilized substratum —made up of hill soil (50%), peat moss (25%), and vermiculite (25%)— was used in the experiment. Fifty seeds were directly sown in the pots. Subsequently, the seeds were covered with a light substratum layer and —in order to increase temperature, decrease evaporation, and speed up germination— the pots were covered with transparent plastic. The experimental units were placed on wooden platforms, which increased the ventilation and water leakage in each irrigation. The first irrigations after the sowing were light and carried out with a watering can, in order to prevent exposing the root due to water impact. As the age of the plant increased, the

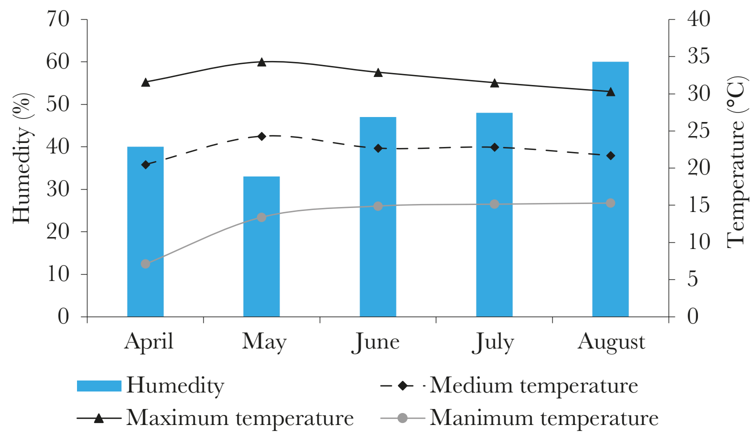

Figure 1. Monthly temperature and humidity recorded from April 25 to August 23, 2022, at the greenhouse of the Departamento de Recursos Naturales, UAAAN-Unidad Saltillo, using a WS08 digital hygrometer.

irrigation consisted of 0.5-1.0 L day^{-1}, until field capacity was reached. A thinning was carried out at 15 DAS, in order to select the three most vigorous individuals of each EU (pot). Successive measurements were carried out every 14 days, from 22 to 120 DAS. These measurements matched eight treatments (plant age), with 5 repetitions each and three individuals.

Evaluated variables

Dry matter yield and morphological components

Destructive sampling consisted of the extraction of whole plants. Afterwards, the roots were washed and placed in previously labelled plastic bags. Subsequently, the aerial parts of the plants were separated from the roots; they were then weighted and the length of each plant was measured. The aerial part was divided into three strata of the same length, according to the age of the plant: basal (BS), middle (MS), and upper or apical (AS) strata. Each stratum was divided into its morphological components: leaves, stem, dead material (DM), and inflorescence. The samples were placed in labelled paper bags and dried in a forced air oven (POM-246F, Serial No. P6-800), at 55 °C for 72 h or until they reached a constant weight. Once they were dehydrated, total and per component dry matter yield was estimated (average of the three plants).

Leaf area

The iMAGEJ software (Rasband, 2007) was used to estimate the leaf area (LA) of fresh leaf blade samples. The leaves were arranged on a previously labelled white sheet, which included the data of the sample and a centimeter scale, based on Rincón-Carruyo *et al.* (2012).

Plant height

Before each sampling, the height of all the individuals of each EU was estimated using a ruler. The ruler had a device that allowed a higher accuracy (Rojas-García *et al.*, 2021).

Leaf:stem ratio

The dry weight of the leaf/stem of each substratum was divided. This operation was based on the morphological composition at 50 DAS, because, from 22 to 36 DAS, the presence of the stem was practically null and the L:S ratio formula could not be applied.

Aerial part:root ratio

This ratio was calculated dividing the dry weight of all the aerial components (leaves, stem, dead material, and inflorescence) per stratum and repetition by the root dry weight.

Statistical analysis

The PROC GLM procedure of the SAS software (Statistical Analysis System, v. 9.4 for Windows; SAS Institute, Cary, NC, USA) and Tukey's means comparison test ($p<0.05$) were carried out for the statistical analysis.

RESULTS AND DISCUSSION

Dry matter yield per stratum

The average dry matter yield per *B. curtipendula* stratum recorded a 16.4, 9.1, and 3.8 g plant^{-1} trend for BS, MS, and AS, respectively ($p\leq0.05$; Figure 2). From 22 to 50 DAS, the dry matter produced per stratum recorded no significant statistical differences ($p\geq0.05$) regarding the DAS averages and the average fluctuated between 0.018 and 0.37 g plant^{-1}. From 50 to 120 DAS (study period), the BS statistically surpassed the MS and AS, accumulating a maximum of 39.1 g plant^{-1} dry matter. AS was the stratum that made the lowest contribution to the total yield per plant, recording a maximum of 11.7 g plant^{-1}, at 120 DAS (Figure 2). In this regard, Sánchez-Arrroyo *et al.* (2020) proved that, based on its DMY results, the NdeM-303 (*B. curtipendula*) genotype have better foraging characteristics than other commercial varieties. For their part, Quero-Carrillo *et al.* (2018) registered a 2.5 g plant^{-1} average yield, in samplings cut with 20-day intervals. Finally, Morales-Nieto *et al.* (2016) studied *banderita* grass populations under similar greenhouse conditions, reporting a 4.0-260 g plant^{-1} dry matter average.

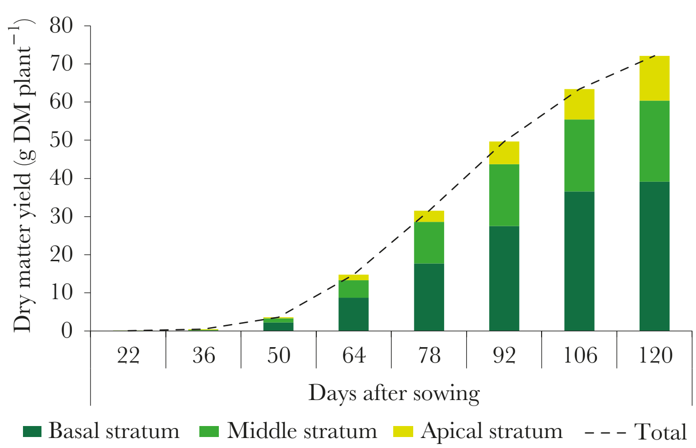

Figure 2. Dry matter yield (g MS plant^{-1}) of *banderita* grass, harvested at different DAS, in three plant strata, during the spring-summer growing cycle.

Morphological composition

At the beginning of the plant's growth (22-36 DAS), the leaves of the BS recorded the highest total yield. Nevertheless, from 50 to 120 DAS, the stem surpassed all the other components ($p \leq 0.05$; average: 12.3 g plant^{-1}), followed by the leaves (2.4 g plant^{-1}), and the dead material (1.7 g plant^{-1}). Since this species shows a trend towards an erect growth, inflorescence was not registered throughout the evaluation in this stratus (Figure 3). In this plant stratum, the stem accounted for 60% of the total yield average, statistically surpassing the leaves (34%), the dead material (5%), and inflorescence (0%) ($p \leq 0.05$) (Figure 3). In addition, from the beginning of the evaluation until 22-64 DAS, the leaves recorded the highest value of all the components in the MS. However, along with the rest of the components, the leaves were surpassed by the stem, at the end of the evaluation period (78-120 DAS). The dead material and the inflorescence always obtained lower values than the leaves and the stems. Nevertheless, unlike what happened in the BS, inflorescence appeared in the MS from 64 DAS (Figure 3). The average dry matter accumulation per component recorded the following sequence: stem>leaf>inflorescence>dead material (4.8>2.0>1.3>0.9 g MS plant^{-1}). The contribution of the morphological components to total plant yield in the MS was more homogenous than in the BS: the leaves recorded the highest average (48%), followed by the stem (39%), inflorescence (7%), and dead material (5%) (Figure 3). Like in the lower strata, leaves registered the highest dry matter yield in the AS of the plant (0.01 and 0.9 g plant^{-1}), at 64 DAS, with 65 to 99% ratios. This situation indicates that plants in the AS are mostly made up of leaves, followed by 1-35% (stem), 0-17% (inflorescence), and 0% (dead material). However, as the plant grows older (78 DAS), the presence of inflorescence surpassed the leaves, stem, and dead material, achieving a 11.6 g plant^{-1} maximum yield, at 120 DAS. This yield accounts for a 99% contribution and a null presence of the stem and leaves, and just 1% dead material (Figure 3). The yield and contribution average of the components showed an inflorescence, leaf, stem, and dead material trends of 86, 10, 3, and 1, respectively. Consequently, as the plants grew older, significant changes were registered in the morphological components of the different strata (Figure 3). In their study, Ramírez-Meléndez *et al.* (2020) recorded differences in the dates and caryopsis of the morphological components, at 56, 67, 81, and 96 DAS, particularly a large caryopsis (0.0005-0.0010 g) for bigger leaves and roots, as well as an increase in total yield. For their part, Morales-Nieto *et al.* (2008) described the morphology of the native *banderita* grass populations and found that the foraging potential of this species is related to its stem production.

Leaf area

There were no differences regarding the leaf area per plant strata between the 22 and 36 DAS ($p \geq 0.05$), because the number of leaves (0.01-0.90 g plant^{-1}) was similar (Figure 3), while the leaf area values fluctuated between 1.9 and 15.9 cm^2 plant^{-1} (Figure 4). From 50 to 120 DAS, the values were higher in the MS, reaching a maximum leaf area of 567.6 cm^2 plant^{-1} at 78 DAS. The greatest total leaf area recorded at 92 DAS was 1,082.2 cm^2 (8.8 g plant^{-1}). There were no statistical differences between BS and MS ($p > 0.05$): 191 and 216 cm^2 plant^{-1} were recorded for BS and MS, respectively. Meanwhile, AS registered

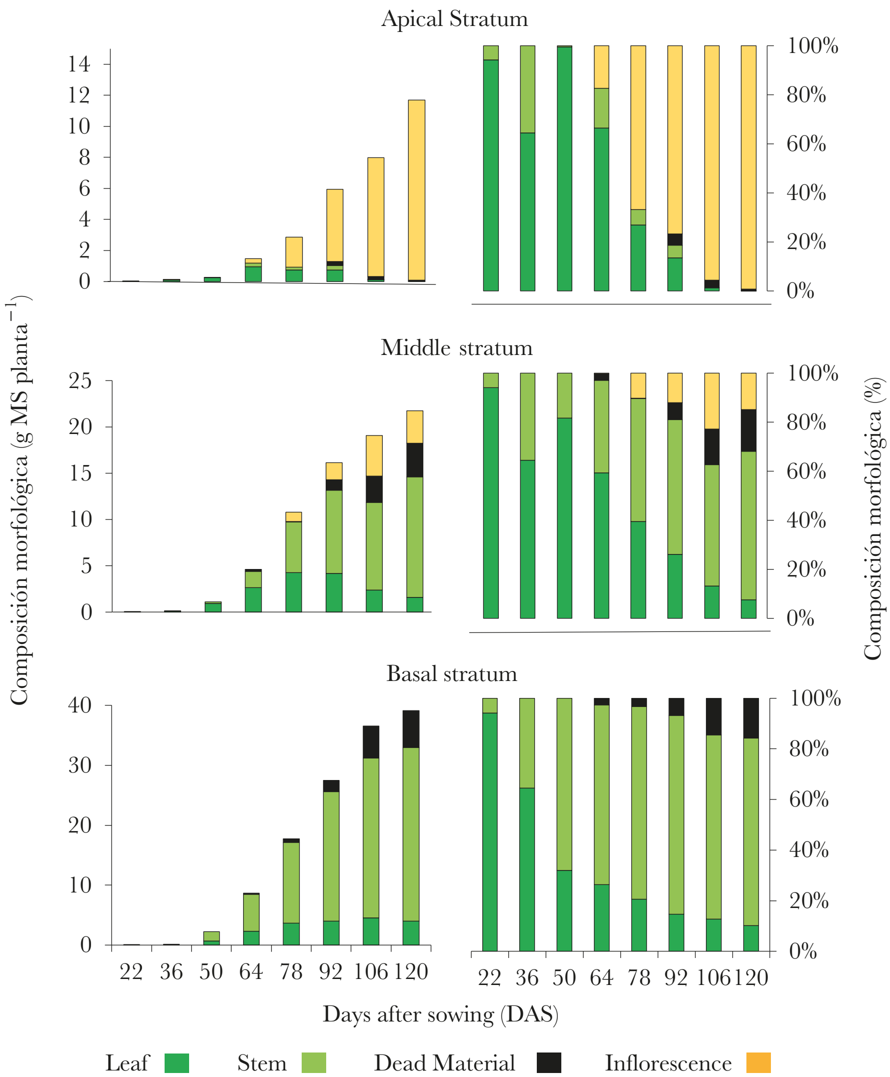

Figure 3. Morphological composition (gr MS plant^{-1}) and percentages of *banderita* grass [*Bouteloua curtipendula* (Michx) Torr] using different plant strata and DAS, during the spring-summer cycle.

a lower value (47 cm^2 plant^{-1}). This difference may explain the low number of leaves on the AS, which is mostly occupied by inflorescence (90%). Pérez-Amaro *et al.* (2004) recorded LA four weeks after the plants were established (28 DAS). For their part, Fagundes *et al.* (2001) recorded leaf area values that fluctuated between 0.21 and 3.7 cm^2, at plant heights between 5 and 20 cm. Meanwhile, Velazco *et al.* (2001) mentioned that a larger leaf area is recorded in summer, when plants experience better growth conditions.

Plant height

The PH of the *banderita* grass (*Bouteluoa curtipendula*) increased as the plant grew older (Figure 5). The maximum PH was 93 (106 DAS) and 96 (120 DAS) ($p>0.05$); therefore, the plant strata under study had a 37.6 cm average length. At 22 and 36 DAS, with a lower height (PH: 13 and 21 cm), the plant strata were established between 4.3 and 7.0

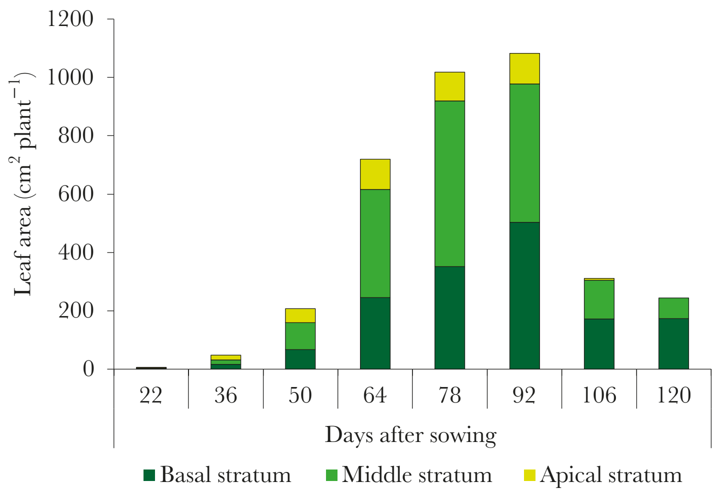

Figure 4. Leaf area (cm^2) of *banderita* grass, harvested at different DAS, in three plant strata, during the spring-summer growing cycle.

cm, showing that the changes in the morphological components are related to plant height at an older age. More leaves can be found in the lower strata of younger plants, while inflorescence prevails in the upper strata of older plants (Figure 3). Morales-Nieto *et al.* (2008) analyzed the main components of the plant and they found that the foraging potential of *banderita* grass (*B. cutipendula*) is one of the main variables that determine plant height. This result accounts for 63.32% of the variation between the studied ecotypes. In addition, heights between 29.9 and 50.0 cm were reported for the Coahuila ecotypes. Meanwhile, Morales-Nieto *et al.* (2016) carried out a morphological and molecular characterization of *banderita* grass populations and reported that plant height varied between 40 and 104 cm.

Leaf:stem ratio

Although the leaft:stem ratio recorded a decreasing trend (L:SR) (Figure 6), no values were recorded in the first cut, as a result of the minimum weight of the stem —resulting

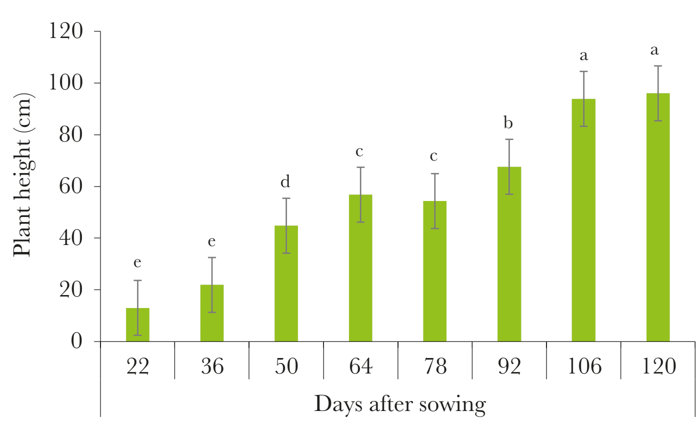

Figure 5. Plant height of *banderita* grass [*Bouteloua curtipendula* (Michx.) Torr.], during the spring-summer season (SSS), at different days after the sowing. Similar letters on top of the bars are not statistically different (Tukey; $\alpha > 0.05$).

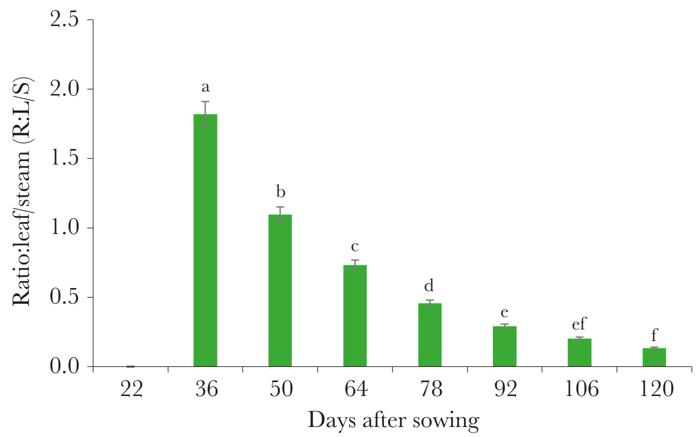

Figure 6. Leaf:stem ratio of *banderita* grass [*Bouteloua curtipendula* (Michx.) Torr.], during the spring-summer season. * L:SR was not estimated at 22 DAS, due to the lack of stems. Similar letters on top of the bars are not statistically different (Tukey; α=0.05).

from the morphological composition of this phenological stage. The ratio recorded its maximum value ($p<0.05$) at 36 DAS (1.82), while the lowest values were obtained at 92, 106, and 120 DAS (0.29, 0.20, and 0.13, respectively), without statistical differences ($p<0.05$) and a 0.59 average value. Fernández *et al.* (2012) mention that, as the plant grows older, the number of stems increases during the days following the sowing or the regrowth, while the number of leaves decreases. Consequently, establishing the optimal harvest moment is fundamental. In this regard, Pérez *et al.* (2002) recorded values between 1.1 and 1.4, which are similar to the findings of this study. Meanwhile, Madera *et al.* (2013) analyzed elephant grass (*Pennisetum purpureum* L.) and recorded values between 1.24 (at 45 DAS) and 0.39 cm^2 (at 120 DAS). These results indicate that the age of the plant has a negative impact on the leaf area and decreases the senescence of the leaf.

Aerial part: root ratio

Regarding the ratio of the biomass produced, the aerial part recorded a higher ($p<0.05$) average value (2.5) than the roots (Figure 7). The lowest value (1.2) was obtained at 22 DAS; this result was statistically different to the values recorded for the other ages of the plant under study. As the plant grew older, the aerial part:root ratio directly increased regarding DAS, reaching a 3.8 maximum value at 92 DAS. These results showed no statistical difference at 106 (3.2) and 120 (3.5) DAS ($p\geq0.05$). Dalrymple and Dwyer (1967) studied the growth of grasses and reported values of 4.92; these results are similar to the values obtained in this study. The lowest SSS values were 1.28, 1.35, and 1.60, at 22, 36, and 50 DAS, respectively. The aerial part registered a greater weight than the root. For their part, Rincón-Carruyo *et al.* (1997) registered 2.44 and 1.86 values for Buffel grass (*Pennisetum ciliaris* (L.) link) grown at an average temperature of 28 °C. Finally, Melgoza *et al.* (2014) recorded a 1.13:1.9 ratio in rose natal grass (*Melinis repens*).

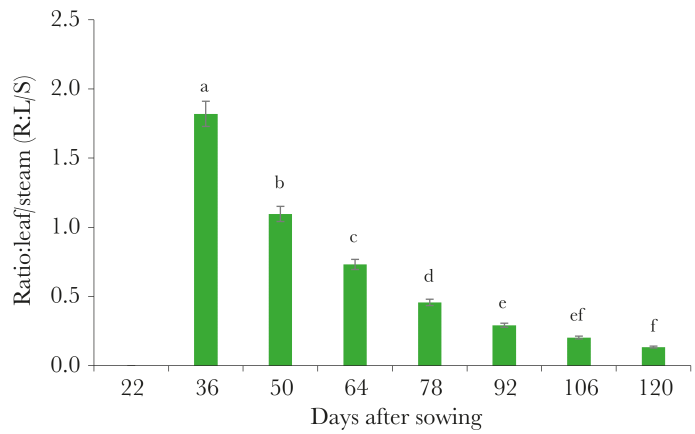

Figure 7. Aerial part:root ratio of the *banderita* grass [*Bouteloua curtipendula* (Michx) Torr], during the spring-summer season, at different DAS. Similar letters on top of the bars are not statistically different (Tukey; α= 0.05).

CONCLUSIONS

During the spring-summer growing cycle, the highest dry matter yield was recorded in the basal stratum of the *banderita* grass (*Bouteloua curtipendula*) plant. Stem made the highest contribution, followed by the leaves, the inflorescence, and the dead material. Nevertheless, the greatest leaf area was registered in the middle stratum of the plant, followed by the basal stratum, and the apical stratum. Height plant and aerial part:root ratio increased as the plant grew older, while the leaf:stem ratio decreased during the days after the sowing.

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