Colegio de Postgraduados

Growth analysis of *Amelichloa clandestina* after intensive non-selective grazing with a high animal load

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Citation: Hervert-Cruz, F., Álvarez-Vázquez, P., Hernández-Guzmán, F., Martínez-Martínez, R., Camposeco-Montejo, N., & Ruelas-Chacón, X. (2025). Growth analysis of *Amelichloa clandestina* after intensive non-selective grazing with a high animal load. *Agro Productividad*. https://doi.org/10.32854/10.32854/0snmdn14

Academic Editor: Jorge Cadena Iñiguez
Associate Editor: Dra. Lucero del Mar Ruiz Posadas
Guest Editor: Daniel Alejandro Cadena Zamudio

Received: October 22, 2025.
Accepted: December 14, 2025.
Published on-line: February 18, 2026.

Agro Productividad, 18(12). December. 2025. pp: 105-116.

ABSTRACT

Objective: To determine the maximum dry matter production of Mexican needlegrass (*Amelichloa clandestina*) following an initial grazing with high stocking density and to provide recommendations for subsequent utilization.

Design/Methodology/Approach: The growth rate (kg DM ha^{-1} day^{-1}), morphological components, leaf-to-stem ratio, and plant height of Mexican needlegrass (*Amelichloa clandestina*) were evaluated through monthly sampling over an 18-month period. A randomized block design with three replications was employed.

Results: Statistically significant differences were observed between regrowth months. The highest dry matter accumulation occurred in winter at 16 months, with a growth rate of 4.2 kg DM ha^{-1} day^{-1}, a maximum plant height of 22 cm, and a leaf yield of 2.3 kg DM ha^{-1} day^{-1}. In contrast, spring showed greater productivity, with peak dry matter production recorded at 14 months (8.4 kg DM ha^{-1} day^{-1}), reaching a maximum height of 43 cm at 18 months. The leaf-to-stem ratio in spring was 4.0, compared to 7.2 in winter.

Limitations/Implications: The results may be affected by local environmental conditions specific to the region, which could limit generalization to other geographic areas.

Findings/Conclusions: A second grazing can be scheduled fewer than six months after the initial regrowth of *Amelichloa clandestina* in southeastern Coahuila, Mexico, especially when grazed under high stocking density in early spring. This is due to the higher growth rate observed in spring compared to winter.

Keywords: *Amelichloa clandestina*, Mexican needlegrass, growth rate, intensive non-selective grazing, morphological composition.

INTRODUCTION

The species *Amelichloa clandestina* (Hack.) Arriaga & Barkworth, commonly known as Mexican needlegrass, is a grass species that tends to colonize abandoned agricultural

lands due to its high adaptability and aggressive spread. It has been identified in the southeastern region of Coahuila, as well as in the states of Nuevo León and Chihuahua, where it is considered endemic. However, because of its hardiness and leaf morphology, it is generally regarded as difficult to utilize through conventional grazing practices (Arriaga & Barkworth, 2006; Juanes-Márquez, 2021). Consequently, Alonso-Díaz *et al.* (2007) suggest that an intensive rotational grazing system can enhance pasture utilization by increasing harvest efficiency, with grazing intensity measured by the length or amount of leaf tissue remaining after grazing (Borrelli & Oliva, 2014). In this context, the use of Mexican needlegrass under high stocking density referred to as Non-Selective Intensive Grazing (NSIG) emerges as a viable strategy for rangeland management in livestock systems (Mendoza *et al.*, 2015; Nai-Bregaglio *et al.*, 2002), and for reducing CO_2 emissions, positioning it as a more environmentally sustainable approach (Milera-Rodríguez *et al.*, 2019). This practice requires a thorough assessment of grazing frequency and intensity across different seasons to evaluate its impact on yield, development, and the regrowth capacity of herbaceous vegetation through growth analysis (Bustamante-García, 2017; Cruz-Hernández *et al.*, 2011). Growth analysis is a widely used technique for identifying physiological differences between varieties or genotypes within a species. In recent years, it has gained importance in the characterization and selection of genotypes aimed at evaluating their forage potential and meeting specific production criteria (Álvarez-Holguín *et al.*, 2017). Additionally, determining dry matter (DM) content is essential for quantifying available forage in a given area. This can be assessed based on the number of days after plant emergence or the months after regrowth (MAR). Dry matter production can be influenced by several factors, including soil type, the duration of the regrowth period before sampling, and the maximum height the forage can achieve within that time. Other valuable indicators include the leaf-to-stem ratio, which quantifies the proportion of edible leaf relative to the supporting stem structure (Assis *et al.*, 2023). Therefore, the aim of this study was to assess the regrowth capacity of Mexican needlegrass following non-selective intensive grazing under both winter and spring conditions, and to identify the period of highest growth rate to inform recommendations for subsequent grazing.

MATERIALS AND METHODS

This study was conducted at "Los Ángeles" Ranch, owned by the Universidad Autónoma Agraria Antonio Narro (UAAAN), located in the municipality of Saltillo, Coahuila, Mexico, at coordinates 26° 06' N and 101° 06' W, with altitudes ranging from 2,100 to 2,400 meters above sea level. The climate is semi-arid, with 86.7% of annual precipitation occurring in the spring-summer period and 13.3% in autumn-winter, totaling approximately 350 mm annually (García, 2004). The study area was a grassland dominated by Mexican needlegrass (*Amelichloa clandestina*), covering approximately 54.6 hectares. An experimental area of 2,200 m^2 was selected and divided into three plots (replicates) of 600 m^2 each (10×60 m) for each evaluation season, resulting in six total plots. Disturbance was applied at the beginning of the winter and spring seasons through high-density grazing at a stocking rate of 350 AU ha^{-1} for 48 hours or until forage availability was depleted (Gür *et* *al.*, 2015). Evaluations were carried out over an 18-month period following grazing: from January 2023 to August 2024 for winter, and from March 2023 to August 2024 for spring. To estimate growth rate, total dry matter yield (DMY) was calculated and divided by the number of days post-regrowth (kg DM ha^{-1} day^{-1}). Each month, four *A. clandestina* plants were harvested from a 1 m^2 area per replicate within each season. Harvested material was placed in paper bags and oven-dried at 60 °C for 48 hours to constant weight (Juanes-Márquez *et al.*, 2022). A subsample was separated into morphological components: leaves, stems, dead matter, and inflorescences, and the contribution of each component was calculated (kg DM ha^{-1} day^{-1}). Plant height was measured using a ruler method with 12 readings per plot (Rojas-García *et al.*, 2021). To determine the leaf-to-stem ratio (L:S), 10 stems were randomly selected and dried, and leaves and stems were separated and weighed (Rojas-García *et al.*, 2018). To assess the effect of regrowth month and identify the maximum total and component-specific growth rates, an analysis of variance (ANOVA) was conducted using the PROC GLM procedure in JMP Pro software. Mean comparisons were performed using Tukey's test ($p<0.05$). Additionally, a factorial analysis was carried out to evaluate the main effects and interactions between season (S) and months after regrowth (MAR) (S×MAR).

RESULTS AND DISCUSSION

Significant differences were found for all main factors and their interaction ($p<0.05$; Table 1). Variables such as growth rate (GR), plant height (PH), and leaf-to-stem ratio (L:S) showed statistically significant differences ($p<0.05$) for season (S), months after regrowth (MAR), and their interaction (S×MAR).

Table 2 presents the mean comparisons for the main factors. Regarding season, the highest growth rate was observed when grazing was performed in March (spring), reaching 3.4 kg DM ha^{-1} day^{-1}, with a maximum plant height of 23 cm. Conversely, grazing in January (winter) resulted in a higher L:S ratio of 3.1, though this difference was not statistically significant compared to spring ($p>0.05$). As for regrowth months, the highest growth rate occurred at the fourteenth month ($p<0.05$), with a value of 5.3 kg DM ha^{-1} day^{-1}. The greatest plant heights were recorded in the sixteenth, seventeenth, and eighteenth months, measuring 23, 29, and 32 cm, respectively. In contrast, the highest L:S

Table 1. Mean Squares of Seasonal Evaluation at Different Months After Regrowth (MAR) in Mexican Needlegrass (*Amelichloa clandestina* (Hack) Arriaga & Barkworth), Following High Stocking Density Grazing.

Source of Variation	df	GR (kg DM ha^{-1} day^{-1})	PH (cm)	L:S Ratio
Season (S)	1	86.4*	511.3*	8.4*
Months After Regrowth (MAR)	17	16.52*	104.5*	9.4*
S×MAR	17	4.4*	49.3*	5.7*
CV (%)		1	0	1

*df: degrees of freedom; GR: growth rate; PH: plant height; L:S: leaf-to-stem ratio; MAR: months after regrowth; S: grazing season; CV: coefficient of variation. *Indicates significant difference ($p\leq0.001$).

Table 2. Mean Comparison of Evaluated Factors at Different Months After Regrowth (MAR) in Mexican Needlegrass (*Amelichloa clandestina* (Hack) Arriaga & Barkworth) Following High Stocking Density Grazing.

Study Factor	GR (kg DM ha^{-1} day^{-1})	PH (cm)	L:S Ratio
Grazing Season (S)			
Winter	1.6^{b}	19 ^{b}	3.1^{a}
Spring	3.4^{a}	23^{a}	2.5^{a}
Months After Regrowth (MAR)			
1	0.3^{e}	10^{c}	2.3^{bcd}
2	0.2^{e}	17^{c}	1.5 ^{cd}
3	0.2^{e}	19^{bc}	0.6^{d}
4	0.8^{de}	20^{b}	1.6^{d}
5	1.2^{de}	21^{b}	2.3^{cd}
6	1.8^{bcde}	21^{b}	3.0 ^{abcd}
7	1.6^{bcde}	22^{ab}	2.6 ^{abcd}
8	1.5^{bcde}	22^{ab}	2.3^{bcd}
9	2.2^{bcde}	21^{b}	4.0^{abc}
10	2.2^{bcde}	20^{b}	4.8^{ab}
11	2.7^{bcde}	20^{b}	5.1^{a}
12	2.7^{bcde}	19^{bc}	5.1 ^{a}
13	4.5^{abc}	20^{bc}	4.0^{abc}
14	5.3^{a}	19^{bc}	2.8^{abcd}
15	4.7^{ab}	21^{b}	3.0^{abcd}
16	4.5^{abc}	23^{ab}	3.1^{abcd}
17	3.8^{abcd}	29^{ab}	3.6^{abc}
18	3.6^{abcd}	32^{a}	2.3^{bcd}

Means with the same letter within each column and factor are not statistically different (Tukey, 0.05). GR: growth rate; PH: plant height; L:S: leaf-to-stem ratio.

ratios were observed in the mid-regrowth period, around the eleventh and twelfth months, with values of 5.1.

Growth rate

Figure 1 presents the results of an 18-month regrowth evaluation under two seasonal conditions. For the pasture grazed in winter, the highest growth rate was recorded at the 16th month after regrowth, reaching 4.2 kg DM ha^{-1} day^{-1}. This represents a notable increase compared to the first month of regrowth, which showed a production of only 0.1 kg DM ha^{-1} day^{-1} ($p<0.05$). However, a decline was observed at months 17 and 18, with values of 3.6 and 3.5 kg DM ha^{-1} day^{-1}, respectively, showing no significant difference among these final three months ($p>0.05$). In contrast, for the pasture grazed in spring, biomass accumulation increased substantially during the 13^{th} and 14^{th} months, with the peak growth rate recorded at the 14^{th} month, reaching 8.4 kg DM ha^{-1} day^{-1}, followed by a significant decline ($p<0.05$). These findings indicate that once the maximum

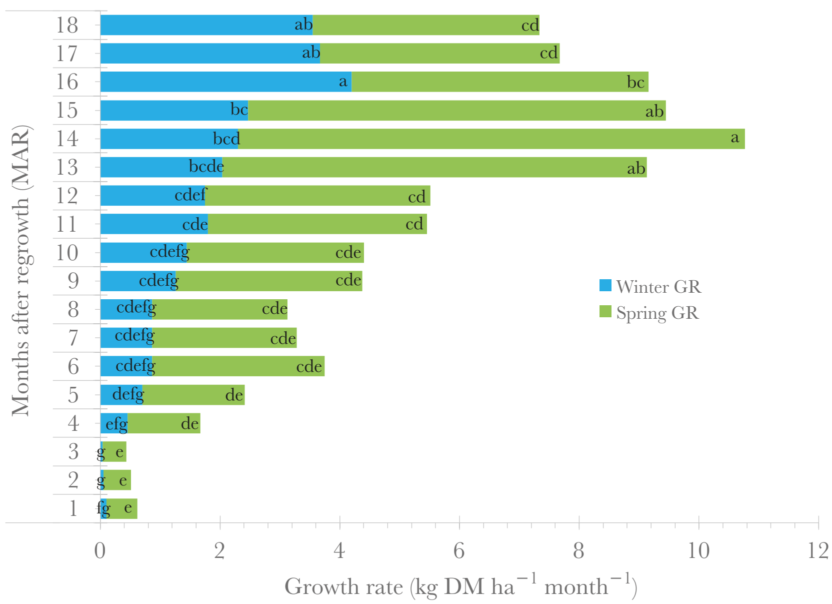

Figure 1. Monthly Growth Rate of Mexican Needlegrass (*Amelichloa clandestina* (Hack.) Arriaga & Barkworth) Following Non-Selective Intensive Grazing Conducted in January and March. Different letters between regrowth months indicate statistically significant differences (Tukey; $p<0.05$).

growth rate is achieved, production begins to decline in both seasons. However, grazing initiated in March (spring) resulted in a higher growth rate in a shorter period compared to January grazing (winter), with a two-month advantage and a difference of 4.2 kg DM ha^{-1} day^{-1}, demonstrating a more favorable regrowth response following non-selective intensive grazing. Juanes-Márquez (2021) reported a maximum growth rate of 4.6 kg DM ha^{-1} day^{-1} at 11 months of regrowth when Mexican needlegrass was harvested during the first defoliation in spring (May 30, 2019). In that study, the effects of manual cutting, herbicide application, and an undisturbed control were compared, showing that manual defoliation promoted better regrowth than both the herbicide treatment and the unperturbed control. In contrast, the results of the present study suggest that high stocking density grazing leads to even better pasture recovery and a higher growth rate. In other grassland species such as sideoats grama (*Bouteloua curtipendula*), Soto-Rojas *et al.* (2024) reported a maximum growth rate of 16.6 g DM plant^{-1} day^{-1} at 120 days (4 months), a result comparable to that of Molina-Salazar *et al.* (2024), who observed yields of 3.98 g DM plant^{-1} day^{-1} at 126 days. Villarreal-González *et al.* (2014) reported a net growth rate of 280.14 kg DM ha^{-1} day^{-1} and a seasonal forage accumulation rate of 107 kg DM ha^{-1} day^{-1} in orchardgrass (*Dactylis glomerata* L.) under intensive summer grazing, 28 days after regrowth. Rojas-García *et al.* (2024) noted that in Mulato II grass (*Brachiaria* hybrid CIAT 36087), the highest growth rate occurred during the rainy season, reaching 36.73 kg DM ha^{-1} day^{-1} after manual cutting at 49 days of regrowth. In intensive forage systems with *Brachiaria decumbens* and *Brachiaria ruziziensis*, even higher values exceeding 200 kg DM ha^{-1} day^{-1} have been reported (Assis *et al.*, 2023). These findings underscore the critical role of environmental conditions, evaluation timing, and rest periods in biomass production. Longer rest intervals between grazing events allow for greater forage accumulation, which is also influenced by the defoliation method employed (Castro-Rivera *et al.*, 2013; Cruz-Hernández *et al.*, 2011).

Morphological composition

The results for the morphological components after grazing in winter and spring are presented in Tables 3 and 4. A significant increase in yield components of Mexican needlegrass was observed with advancing regrowth age ($p<0.05$), with leaves being the dominant component throughout the evaluation period. The highest leaf production coincided with the peak growth rate during winter grazing (Figure 1), specifically at the 16th month of regrowth, contributing 2.3 kg DM ha^{-1} day^{-1} in leaf yield. This was followed by leaf senescence, reflected in the increase in dead matter ($p<0.05$). Similarly, in the spring grazing evaluation, the highest leaf yield occurred at the 13th month of regrowth, contributing to a growth rate of 4.2 kg DM ha^{-1} day^{-1}. However, the peak total dry matter accumulation was observed at the 14th month, with a leaf yield of 3.8 kg DM ha^{-1} day^{-1}. Regarding stem production in the winter grazing treatment, the pattern mirrored that of leaf yield, with the highest stem contribution of 1.0 kg DM ha^{-1} day^{-1} observed at the 16th month. No significant differences were found between the 16th, 17th, and 18th months ($p<0.05$). In contrast, in the spring treatment, the highest stem production occurred at the 14th month, reaching 2.4 kg DM ha^{-1} day^{-1}, followed by a

Table 3. Morphological Composition (kg DM ha^{-1} day^{-1}) of Mexican Needlegrass (*Amelichloa clandestina* (Hack) Arriaga & Barkworth) Following Non-Selective Intensive Grazing Conducted in January (Winter).

MAR	Leaf	Stem	Dead Matter
1	0.06 ^{ef}	0.03 ^{b}	0.001 ^{d}
2	0.04 ^{f}	0.02 ^{b}	0.001 ^{d}
3	0.03 ^{f}	0.01 ^{b}	0.002 ^{d}
4	0.4 ^{def}	0.04 ^{b}	0.04 ^{d}
5	0.6 ^{cdef}	0.05 ^{b}	0.06 ^{d}
6	0.8 ^{bcdef}	0.06 ^{b}	0.07 ^{d}
7	0.8 ^{bcdef}	0.06 ^{b}	0.07 ^{d}
8	0.8 ^{bcdef}	0.06 ^{b}	0.07 ^{d}
9	1.0 ^{bcdef}	0.08 ^{b}	0.3 ^{bcd}
10	0.9 ^{bcdef}	0.13 ^{b}	0.1 ^{cd}
11	1.1 ^{bcdef}	0.07 ^{b}	0.3 ^{abcd}
12	1.1 ^{bcde}	0.08 ^{b}	0.2 ^{bcd}
13	1.4 ^{abcd}	0.03 ^{b}	0.3 ^{bcd}
14	1.3 ^{abcd}	0.08 ^{b}	0.7 ^{ab}
15	1.8 ^{ab}	0.15 ^{b}	0.2 ^{bcd}
16	2.3 ^{a}	1.0 ^{a}	0.6 ^{abc}
17	1.9 ^{ab}	0.9 ^{a}	0.6 ^{ab}
18	1.6 ^{abc}	0.7 ^{a}	0.8 ^{a}

Means with the same letter within each column are not significantly different (Tukey, $p<0.05$). MAR: Months After Regrowth.

Table 4. Morphological Composition (kg DM ha^{-1} day^{-1}) of Mexican Needlegrass (*Amelichloa clandestina* (Hack) Arriaga & Barkworth) Following Non-Selective Intensive Grazing Conducted in March (Spring).

MAR	Leaf	Stem	Dead Matter
1	0.3^{ef}	0.1^{d}	0.03^{d}
2	0.2^{ef}	0.1^{d}	0.03^{d}
3	0.2^{f}	0.1^{d}	0.06^{d}
4	0.4^{def}	0.08^{d}	0.06^{d}
5	2.0^{cd}	0.1^{d}	0.2^{cd}
6	2.6^{abc}	0.4^{cd}	0.5^{cd}
7	1.8^{cdef}	0.1^{d}	0.3^{cd}
8	1.9^{cde}	0.05^{d}	0.4^{cd}
9	2.0^{cd}	0.3^{d}	0.6^{cd}
10	2.6^{abc}	0.03^{d}	0.7^{cd}
11	3.0^{abc}	0.06^{d}	0.7^{cd}
12	2.5^{abc}	0.3^{d}	0.5^{cd}
13	4.2^{a}	1.7^{ab}	0.7^{cd}
14	3.8^{ab}	2.4^{a}	2.3^{a}
15	3.3^{abc}	1.2^{bc}	1.9^{ab}
16	2.3^{bc}	0.9^{bcd}	1.2^{bc}
17	1.7^{cdef}	0.4^{cd}	1.1^{bc}
18	1.8^{cdef}	0.6^{cd}	1.0^{bcd}

Means with different letters within each column indicate statistically significant differences (Tukey, $p<0.05$). MAR: Months After Regrowth.

significant decline ($p<0.05$). In both evaluations, an increase in dead matter was noted toward the later stages of regrowth. In the winter treatment (Table 3), dead matter peaked at the 18th month, reaching 0.8 kg DM ha^{-1} day^{-1}. This coincided with a clear decline in leaf growth rate, linking the accumulation of dead material to reduced leaf productivity. Similarly, in the spring treatment (Table 4), the highest dead matter yield occurred at the 14th month (2.3 kg DM ha^{-1} day^{-1}), corresponding with a decrease in leaf yield. In the spring evaluation (Table 4), although the 14th month showed the highest overall growth rate (Figure 1), it also marked the peak in stem and dead matter content both considered of lower nutritional value for grazing livestock. Previous studies have shown that, following peak leaf production, a decline typically occurs due to basal leaf senescence caused by plant self-shading (Calzada-Marín *et al.*, 2014). Azumi and Watanabe (1991) also noted that this senescence is related to a reduction in photosynthetic activity, resulting in tissue death due to aging, environmental conditions, or grazing management. Álvarez-Vázquez *et al.* (2023) reported a leaf growth rate of 65.7 mg DM $plant^{-1}$ day^{-1} and a stem growth rate of 25.1 mg DM $plant^{-1}$ day^{-1} for sideoats grama (*Bouteloua curtipendula*) at 30 days post-emergence values lower than those observed during the first regrowth month in the present study. Changes in morphological composition between treatments are likely influenced by edaphic and climatic conditions, as well as by the intensity of grazing (Cruz-Hernández *et al.*, 2011).

Plant height

Throughout the evaluation period, plant height in the pasture grazed in January (Figure 2), under winter climatic conditions, exhibited a significant increase ($p<0.05$) during the first four months of regrowth. Beyond this stage, no statistically significant differences were detected ($p>0.05$), although the maximum height of 22 cm was recorded at the 16th month of regrowth. This increase, while not statistically different from previous months, is noteworthy as it coincided with the highest growth rate (Figure 1) and peak morphological yield (Table 3). Conversely, under spring conditions, where grazing was conducted in March at high stocking density (Figure 2), plant height increased steadily throughout the entire evaluation period ($p<0.05$). The maximum height was reached at the 18th month of regrowth, requiring more time to achieve than in the winter grazing scenario, which peaked at the 16th month. Plant heights were overall greater in the spring grazing treatment, which correlates with higher growth rates observed at taller plant stages. However, the spring-grazed pasture exhibited some irregular growth, with a temporary decline in height observed from the 8th month onward, followed by exponential growth from the 15th month through the end of the study. This suggests that even after achieving peak growth rates, plants in the spring treatment continued to increase in height due to greater stem accumulation (Table 4). According to Juanes-Márquez (2021), *Amelichloa clandestina* reached a plant height of 36.9 cm after manual cutting in spring at two months of regrowth greater than the 22 cm recorded under winter grazing, but lower than the 43 cm achieved under spring grazing in this study. In contrast, the application of herbicide resulted in shorter plants, with a maximum height of only 17.5 cm. Arévalo *et al.* (2021) reported an average height of 70 cm for this species, which exceeds the values recorded during the current evaluation period. In *Dactylis glomerata*, post-trampling stress resulted in a height of 21 cm, which is lower than the values found in this study. Similarly, for *Panicum*

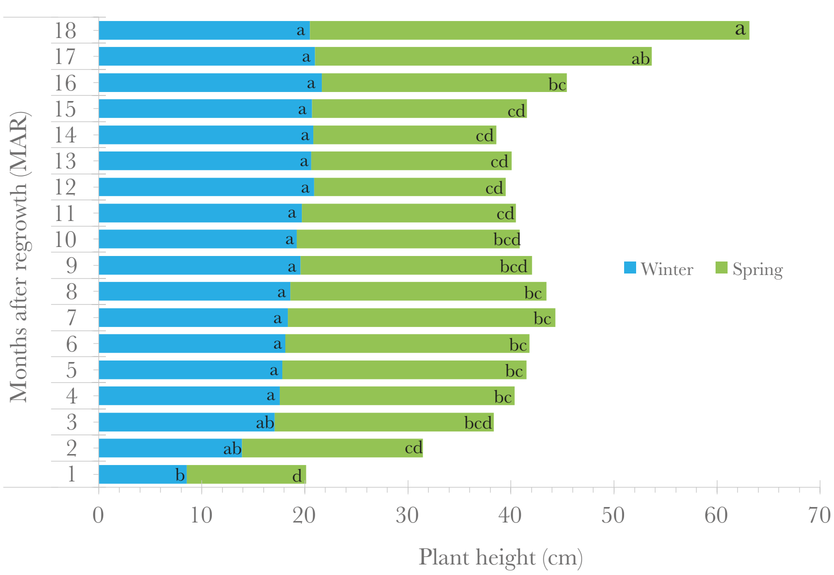

Figure 2. Plant height of spiky grass (*Amelichloa clandestina*) after intensive non-selective grazing carried out in January and March. Different heights between regrowth months of the same treatment are statistically different (Tukey; $p<0.05$).

maximum Jacq. cv. Mombasa, the maximum height was recorded between 70 and 80 days after regrowth in summer, reaching up to 120 cm (Velasco *et al.*, 2018) much higher than the values observed here. Therefore, plant height appears to be directly correlated with growth rate in each treatment, with both increasing in a similar pattern. This is consistent with findings from Mónaco *et al.* (2017), who indicated that plant height can serve as an indirect method for estimating biomass in grasslands.

Leaf-to-stem ratio

Throughout the evaluation period, the evolution of the leaf-to-stem ratio across months after regrowth is presented in Figure 3, comparing grazing initiated in January (winter) and March (spring). A direct relationship was observed between regrowth age and the proportion of dry matter yield from leaves relative to stems. A higher leaf-to-stem (L:S) ratio indicates a greater proportion of leaf material compared to stem, which is desirable in forage quality. In the winter grazing treatment, the L:S ratio increased significantly, peaking at the 12th month of regrowth with a value of 7.2, followed by a significant decline toward the end of the study ($p<0.05$). Except for the third month of regrowth which recorded the lowest value of 0.5 all other months showed a ratio above 1.0, indicating that leaf biomass consistently outweighed stem biomass for most of the regrowth period.

In contrast, the spring grazing treatment exhibited notable fluctuations in the L:S ratio over time, though with less statistical variability compared to winter. The highest ratio was recorded in the ninth month of regrowth, reaching 4.0 a lower peak than that observed in the winter treatment. However, this maximum value did not differ statistically from most other months ($p>0.05$), except for the third month of regrowth, which showed a value of 1.0 ($p<0.05$). Overall, these results reflect a predominance

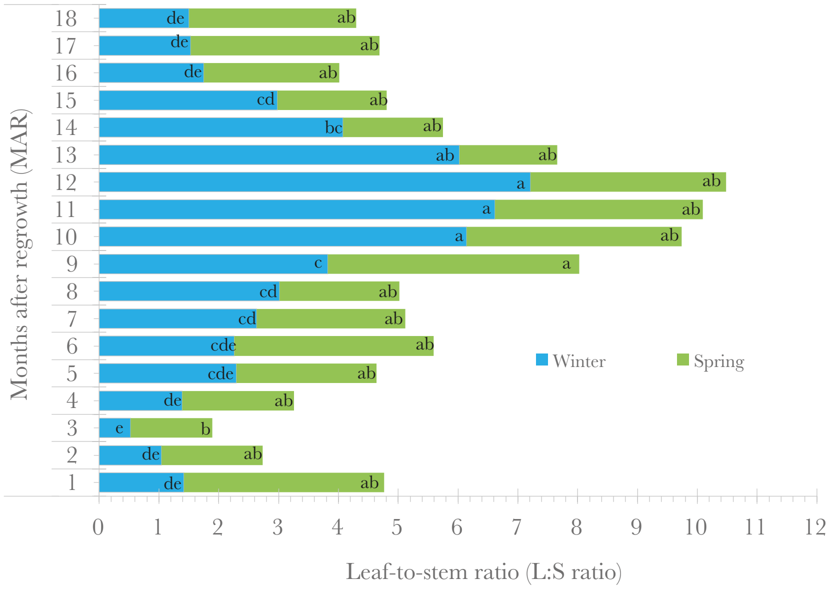

Figure 3. Monthly Leaf-to-Stem Ratio of Mexican Needlegrass (*Amelichloa clandestina*) Following Non-Selective Intensive Grazing Conducted in January and March. Different letters between regrowth months indicate statistically significant differences (Tukey; $p<0.05$).

of leaf biomass over stem biomass throughout the study. These values are considered favorable compared to other forage species grown under more favorable climatic conditions. For example, Calzada-Marín *et al*. (2014) reported a ratio of 1.5 in Maralfalfa grass (*Pennisetum* sp.), and Araya-Mora & Boschini-Figueroa (2005) reported a maximum ratio of 2.6 in *Pennisetum purpureum*. The superior ratios observed in the present study may be attributed to the use of high stocking density grazing, which appeared to enhance leaf production regardless of the season. Conversely, Perozo-Bravo *et al*. (2009) reported a reduction in the L:S ratio from 0.24 to 0.20 under high-intensity grazing, suggesting that grazing pressure can negatively affect this ratio. Similarly, Maya-M *et al*. (2005) reported an L:S ratio of 1.97 in star grass under a 28-day cutting frequency lower than values recorded in this study during the first regrowth month of spring, but still higher than those from the winter grazing treatment.

CONCLUSIONS

High stocking density grazing on Mexican needlegrass (*Amelichloa clandestina*) during the spring season promotes more effective pasture recovery, achieving maximum forage growth rate in a shorter period compared to winter grazing. In spring, a second utilization is feasible at 14 months of regrowth, whereas in winter it requires 16 months. This is supported by favorable morphological development, particularly increased leaf biomass, along with greater plant height and a higher leaf-to-stem ratio.

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