Colegio de Postgraduados

Seasonal regrowth capacity of an *Amelichloa clandestina* (Hack.) Arriaga & Barkworth grassland in northeastern Mexico

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ABSTRACT
Objective: To evaluate yield components and seasonal biomass accumulation of Mexican needlegrass (*Amelichloa clandestina*) at different days after regrowth (DAR) under the environmental conditions of northeastern Mexico.
Design/Methodology/Approach: A completely randomized block design with three replicates was employed, considering days after regrowth within each season as the main study factor. The variables evaluated included dry matter yield (DMY), morphological components (MC), plant height (PH), and light interception (LI).
Results: Maximum DMY was recorded between 75 and 90 DAR during autumn, reaching 546.1 kg DM ha^{-1} ($p \leq 0.05$), with a significant leaf contribution of 382.2 kg DM ha^{-1}. The greatest plant height (47.3 cm) was also observed in autumn at 90 DAR ($p \leq 0.05$), accompanied by 42% light interception. A strong positive correlation was identified between DMY and plant height ($R^2 = 0.83$).
Limitations/Implications: This study was conducted under the specific climatic conditions of northeastern Coahuila, Mexico. Therefore, the applicability of the results may vary under different environmental contexts.
Findings/Conclusions: *Amelichloa clandestina* exhibited its greatest regrowth potential in autumn, as evidenced by increases in dry matter yield and plant height, along with a positive correlation with days after regrowth, outperforming the other seasons evaluated.

Keywords: *Amelichloa clandestina*, dry matter yield, plant height, morphological composition, light interception.

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INTRODUCTION

In northeastern Mexico, Mexican needlegrass (*Amelichloa clandestina* (Hack.) Arriaga & Barkworth) has been identified following the abandonment of agricultural lands and inadequate grazing practices. This species is endemic to the Chihuahuan Desert and possesses a remarkable ability to colonize disturbed areas, thriving in calcareous soils, shrublands, and pine forests at elevations ranging from 800 to 2,100 meters (Villaseñor, 2016). Its national distribution includes the states of Coahuila and Nuevo León, and

according to Russell and Landers (2017), it has also established in western Texas, where it was introduced from Mexico in the 1950s. The presence of this and other native grasses is critical for the persistence and productivity of rangelands, primarily through population density and regenerative capacity, which are key to ensuring the sustainability of livestock production systems (Corral *et al.*, 2011). Moreover, previous studies have highlighted the importance of grazing frequency and intensity across seasons in influencing forage yield, growth, and quality (Domínguez-Escudero *et al.*, 2021), as cutting frequency directly affects forage nutritive value (Montes-Cruz, 2016). This is particularly relevant for Amelichloa clandestina, whose growth behavior may vary considerably depending on local environmental conditions. Therefore, the aim of this study was to evaluate seasonal and total dry matter accumulation in yield components of Mexican needlegrass (*A. clandestina*) at different days after regrowth under the environmental conditions of northeastern Mexico.

MATERIALS AND METHODS

The study was conducted in a grassland area of approximately 32 hectares dominated by *Amelichloa clandestina*, located in northeastern Mexico at coordinates 25° 06' 30" N latitude and 100° 59' 18" W longitude, within the "Los Ángeles" experimental ranch of the Universidad Autónoma Agraria Antonio Narro (UAAAN), in Saltillo, Coahuila (Figure 1). Elevation ranges from 2,100 meters in the valleys to 2,400 meters in the mountainous areas, which defines the region's topography. According to the Köppen climate classification as modified by García (2004), the region is classified as BSokw(e'), indicating a dry climate

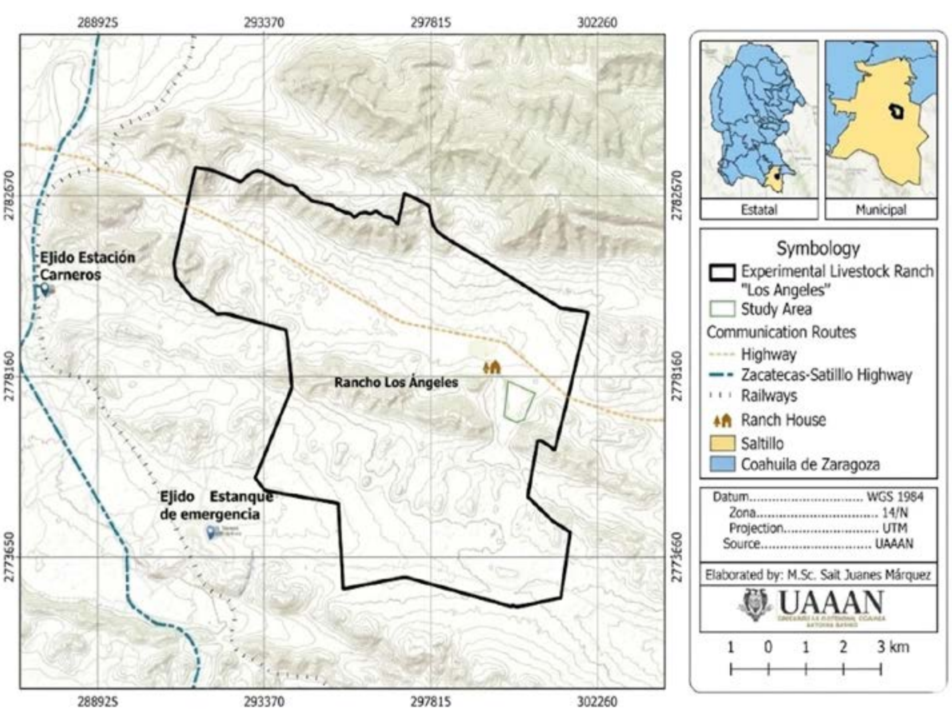

Figure 1. Geographic location of the study area, Rancho Los Ángeles, Saltillo, Coahuila, Mexico (Own elaboration; Sait Juanes Márquez).

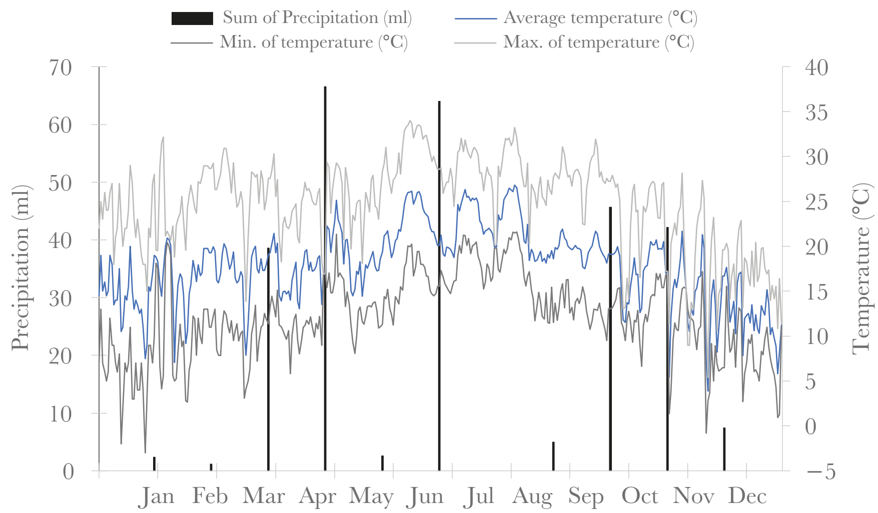

Figure 2. Average daily maximum, average and minimum temperature and accumulated precipitation from January to December 2023.

with a precipitation-to-temperature ratio exceeding 22.9 mm/16 °C. Summers are mild to warm, with average temperatures ranging from 7 to 14 °C (Figure 2). Rainfall is distributed across two distinct periods: from May to October, which accounts for 86.7% of the annual total, and from November to April, representing the remaining 13.3%, with an average annual precipitation of 350 mm (García, 2004).

EXPERIMENTAL METHODOLOGY

Three experimental units of 100 m^2 each (5×20 m) were established for assessment in each season of the year. A uniformity cut was carried out at the beginning of each season, followed by biweekly evaluations. Cuts were performed manually at a height of 10 cm above ground level. The treatments consisted of evaluations based on days after regrowth (DAR) within each season, following the methodology described by Cámara-Acosta *et al.* (2022). Biomass accumulation and morphological components were determined in each experimental plot depending on the season, by harvesting regrowth present in two randomly placed 1 m^2 quadrants. After homogenizing the sample, a 10% subsample was separated into leaf, stem, and dead material components. Both the components and the remaining bulk sample were placed in labeled paper bags and oven-dried in a forced-air oven at 60 °C for 48 hours or until reaching constant weight, to determine dry matter yield (kg DM ha^{-1}) (Muñoz-García *et al.*, 2020). Plant height was determined by averaging 12 random readings per regrowth age and season per replicate. A 100 cm graduated ruler was placed randomly in each plot, with its base flush with the soil surface (Arévalo *et al.*, 2021). To assess light interception percentage, three random readings per replicate were taken before each cut using a Quantum Meter (model MQ-301). Readings were conducted between 12:00 and 13:00 h, placing the meter both above and below the canopy in a south–north orientation to measure incident and transmitted radiation, following the methodology by Mendoza and Álvarez (2022). An analysis of variance (ANOVA) was performed using the PROC GLM procedure in JMP 14 Pro to evaluate the effects of regrowth age, season, and their interaction on the studied variables. A completely randomized block design with three replications was used, with the study factors being days after regrowth within each season. A two-way factorial analysis was applied to assess the main factors Season (S), Days After Regrowth (DAR), and their interaction (S×DAR). Treatment means were compared using Tukey's *post-hoc* test at a significance level of $\alpha=0.05$. Additionally, a linear correlation analysis was performed to assess relationships among variables using JMP 14 Pro.

RESULTS AND DISCUSSION

Significant effects were detected for both main factors and their interaction (Table 1), indicating that the variables under study provided meaningful data. Statistically significant differences ($p\leq0.05$) were observed for both the main effects and their interaction, validating the use of these variables as reliable indicators for interpreting the results obtained.

The statistical analysis of mean comparisons for the main factors revealed that, during the autumn season at 90 days after regrowth (DAR), the highest values were observed across all evaluated variables. Dry matter yield (DMY) peaked at 546 kg ha^{-1}, plant height (PH) reached 38.7 cm, and light Interception (LI) was recorded at 26%, the latter being statistically similar to summer ($p\geq0.05$). Regarding the DAR factor, the highest values were recorded at 75 and 90 DAR, with 389 and 492 kg ha^{-1}, respectively. Likewise, plant height reached 34.6 cm, and IL peaked at 26% at 90 DAR (Table 2). These results suggest a strong seasonal influence on the productive variables of the grassland, as well as on the physiological and morphological variations of the plants. Seasonal variation in dry matter accumulation and plant height is key to understanding how plants adapt to changing environmental conditions. In a study on light interception and dry matter production in *Brassica juncea*, Mandal and Sinha (2004) found that proper nutrient management improved light interception and biomass production, highlighting the importance of optimizing resources such as water and nutrients during critical growth periods.

The analysis of dry matter accumulation revealed significant variation across seasons and days after regrowth (DAR) (Table 3). Highly significant differences ($p\leq0.0001$) were found in dry matter yield (DMY), indicating clear disparities in forage productivity throughout the year. Optimal forage production occurred during the autumn season, particularly at 75 and 90 DAR, with the highest DMY values recorded at 746.7 and 1,442.0 kg ha^{-1}, respectively ($p\leq0.05$). These findings suggest that *Amelichloa clandestina*

Table 1. Mean squares from the seasonal evaluation of *Amelichloa clandestina* at different days after regrowth (DAR) in northeastern Mexico.

Source of Variation	df	DMY (kg DM ha^{-1})	Plant Height (cm)	Light interception (%)
Season (S)	3	949,486*	1847.93*	1732.50*
Days After Regrowth (DAR)	5	265,086*	579.88*	425.26*
S×DAR	15	49,174*	28.23*	40.36
CV (%)	–	31	15	37

*CV=Coefficient of Variation; df=Degrees of Freedom; DMY=Dry Matter Yield; Alt=Plant Height; LI=Light Interception; Significant differences at $p\leq0.001$.

Table 2. Mean comparison of main factors evaluated for *Amelichloa clandestina*, assessed seasonally at different days after regrowth (DAR) in northeastern Mexico.

Factor	DMY (kg DM ha^{-1})	Plant Height (cm)	Light Interception (%)
Season			
Winter	8.6 d	16.3 c	7.6 c
Spring	176.6 c	18.3 c	11.0 bc
Summer	337.9 b	27.0 b	26.0 a
Autumn	546.1 a	38.7 a	26.0 a
Days After Regrowth (DAR)			
15	89.7 c	15.0 d	9.3 e
30	171.0 bc	20.6 c	13.6 de
45	201.6 bc	24.0 c	16.3 cd
60	260.3 b	25.5 bc	19.6 bc
75	389.0 a	30.3 ab	22.0 ab
90	492.0 a	34.6 a	26.3 a

DMY=Dry Matter Yield; PH=Plant Height; LI=Light Interception.
Means within the same factor and column followed by the same letter are not statistically different (Tukey, $p \leq 0.05$).

exhibits a more robust regrowth response under the environmental conditions of autumn. In contrast, the lowest yields were recorded in winter, especially at 15 and 30 DAR, with 5.6 and 7.3 kg ha^{-1}, respectively ($p \leq 0.05$). These low values are likely attributable to adverse environmental conditions such as sudden temperature drops and low relative humidity, which may limit plant growth (Figure 2). In spring and summer, a significant increase in DMY was observed starting at 45 DAR, with maximum values at 75 and 90 DAR —307.6, 381.0, and 492.3, 536.6 kg ha^{-1}, respectively ($p \leq 0.05$). The overall seasonal trend in dry matter production followed the order: autumn > summer > spring > winter ($p \leq 0.05$), clearly reflecting the influence of seasonal conditions on plant regrowth. Kramberger *et al.* (2014) noted that low and erratic rainfall patterns characteristic of northern Mexico significantly impact native vegetation, including *A. clandestina*, which is adapted to arid conditions. These environments, marked by limited water availability, illustrate the physiological and ecological adaptations necessary for plant survival under water stress. Gamalero *et al.* (2020) emphasized the critical interplay between abiotic factors and plant biology in arid ecosystems. These studies underscore the importance of understanding plant adaptive responses to drought and salinity stress, which are essential for conserving biodiversity and ensuring agricultural sustainability in arid regions (Shao *et al.*, 2009; Lewandrowski *et al.*, 2021). In a prior study, Juanes-Márquez *et al.* (2022) evaluated the effect of mechanical harvesting on DMY in *A. clandestina* grasslands. They reported an average yield of 249 kg ha^{-1} in summer, which differed significantly from other seasons: 791 in autumn, 897 in spring, and 911 kg ha^{-1} in winter. These values were recorded one year post-regrowth (339 DAR) and are comparable to those observed in the present study, showing consistent seasonal production patterns in *A. clandestina* pastures. Moreover, forage yield variability in *A. clandestina* appears closely correlated with precipitation patterns throughout the year in the study region (Figure 2). Previous research has shown that forage production in grasslands is notably influenced by this factor, particularly in semiarid areas where water is a limiting resource for native grass growth (Duncan & Woodmansee, 1975; Mirzaali *et al.*, 2011). In this study, the highest forage production periods coincided with months of peak rainfall, highlighting the direct dependence of plant growth and biomass accumulation on water availability. This aligns with findings from other semiarid regions where precipitation is a key determinant of rangeland productivity (White, 1985; Perotti *et al.*, 2021).

The mean comparison of morphological components, based on the study factors outlined in Table 4, revealed significant differences ($p \leq 0.05$) in biomass production across components and seasons. For dry matter yield (DMY), the highest contributions from leaf and stem components occurred during the autumn season, with maximum yields of 382.2 and 130.2 kg ha^{-1}, respectively. In the case of stems, autumn and summer showed statistically similar values ($p \geq 0.05$). Regarding dead material (DM), significant seasonal differences were observed ($p \leq 0.05$), with the lowest values in winter (0.9 kg ha^{-1}) and the highest in autumn (33.7 kg ha^{-1}). These findings suggest a seasonal dynamic in dead biomass accumulation, likely influenced by abiotic factors that vary across the year (Figure 2). Winter was characterized by the lowest production levels across all components: 4.5 kg ha^{-1} for leaf, 3.2 kg ha^{-1} for stem, and 0.9 kg ha^{-1} for dead material. This can be attributed to reduced photosynthetic activity and limited vegetative growth, conditions commonly associated with low temperatures and diminished light availability (Blanco-Valdés, 2019). The DAR factor showed significant patterns in biomass production as regrowth age advanced. All morphological components peaked at 90 DAR, with dry matter yields of 290.2 kg ha^{-1} for leaf, 172.8 kg ha^{-1} for stem, and 29.6 kg ha^{-1} for dead material. This increase reflects an acceleration in foliar growth rate and a dynamic shift toward stem biomass accumulation as the plant matures. Although dead material did not differ significantly in its contribution to total DMY ($p \geq 0.05$), its peak value at 90 DAR (29.6 kg ha^{-1}) suggests that senescence and decomposition processes intensify with plant age. From a practical standpoint, a higher proportion of dead material in forage reduces its utilization by grazing animals due to its lower nutritional value. Therefore, the production

Table 3. Seasonal dry matter accumulation (kg DM ha^{-1}) of *Amelichloa clandestina* evaluated at different days after regrowth (DAR) in northeastern Mexico.

DAR	Winter	Spring	Summer	Autumn	Annual Total
15	5.6 b	42.3 c	54.7 c	255.3 c	357.9
30	7.3 ab	52.0 c	238.3 bc	388.0 c	685.6
45	8.6 a	70.7 c	315.3 abc	411.0 bc	805.6
60	8.6 a	206.6 b	392.0 ab	434.0 bc	1041.2
75	8.3 a	307.6 a	492.3 ab	746.7 ab	1554.9
90	8.6 a	381.0 a	536.6 a	1042.0 a	1968.2
SEM	0.31±	32.56±	44.14±	69.14±	135.70±

Means with the same letter within the same column are not statistically different (Tukey, $p \leq 0.05$). SEM=Standard Error of the Mean.

Table 4. Mean comparison of evaluated factors in morphological components (kg DM ha^{-1}) of *Amelichloa clandestina*, by season and days after regrowth (DAR) in northeastern Mexico.

Factor	Leaf	Stem	Dead Material (DM)
Season			
Winter	4.5 c	3.2 c	0.9 c
Spring	78.3 c	73.4 b	24.9 ab
Summer	183.6 b	139.7 a	14.6 bc
Autumn	382.2 a	130.2 ab	33.7 a
Days After Regrowth (DAR)			
15	58.8 b	27.0 c	3.6 a
30	106.4 ab	47.6 bc	17.3 a
45	126.7 ab	59.1 bc	15.5 a
60	155.1 ab	87.9 abc	17.2 a
75	235.7 ab	125.5 ab	27.7 a
90	290.2 a	172.8 a	29.6 a

DM=Dead Material. Means within the same factor and column followed by the same letter are not statistically different (Tukey, $p \leq 0.05$).

and distribution of biomass in rangelands are heavily influenced by seasonal factors, including temperature and precipitation variability, as well as management practices such as grazing (Kramberger *et al.*, 2014). Research by Wan *et al.* (2015) has shown that plant community structure and biomass allocation respond to the interaction between grazing intensity and rainfall patterns, highlighting the importance of incorporating herbivore dietary preferences into the management of semi-arid rangelands. Similarly, findings by Song *et al.* (2024) demonstrate that off-season precipitation regulates plant community structure and biomass allocation in temperate desert grasslands, indicating significant implications for water and carbon use in these ecosystems.

The analysis of plant height revealed significant differences based on season, days after regrowth (DAR), and their interaction (Table 5). Across all seasons, the highest values were recorded at 90 DAR, following the trend: autumn > summer > spring > winter, with heights of 47.3, 38.3, 30.0, and 23.3 cm, respectively. However, in autumn, no statistical differences were observed among DAR intervals ($p \geq 0.05$). Juanes-Márquez *et al.* (2022) reported that *A. clandestina* reached its greatest height in autumn, averaging 40.7 cm, followed by summer with 35 cm. In contrast, mean heights in winter and spring were 25 cm and 19 cm, respectively. Similarly, Arévalo *et al.* (2021) recorded a maximum plant height of 50 cm after a one-year regrowth period. In addition to seasonal variation, the length of the regrowth period plays a crucial role in the growth potential of the species. These findings indicate that *A. clandestina* exhibits a strong phenotypic response to environmental conditions and extended growth periods without cutting intervention (Gimeno *et al.*, 2009). Moreover, the results suggest a direct correlation between plant height and dry matter yield observed in each season (Table 7), supported by Yiruhan *et al.* (2014), who demonstrated that rainfall patterns during the growing season can predict biomass changes in Mongolian

Table 5. Seasonal average plant height (cm) of *Amelichloa clandestina* evaluated at different days after regrowth (DAR) in northeastern Mexico.

DAR	Winter	Spring	Summer	Autumn	SEM
15	9.0 f	10.3 d	12.3 c	28.7 a	2.39±
30	12.0 d	14.3 c	18.3 c	39.0 a	3.29±
45	15.0 d	15.3 c	29.6 b	36.6 a	2.83±
60	17.6 c	15.3 c	31.0 b	38.0 a	2.83±
75	20.3 b	25.6 b	32.6 ab	42.6 a	2.54±
90	23.3 a	30.0 a	38.3 a	47.3 a	3.39±
SEM	1.94±	1.70±	2.20±	1.93±	

Means with the same letter within a column are not statistically different (Tukey, $p \leq 0.05$). SEM=Standard Error of the Mean.

grasslands. Wingler and Hennessy (2016) also emphasized that the productivity of temperate grasslands is limited by plant responses to low temperatures, which affect winter persistence and seasonal growth rates.

The analysis of light interception (%) revealed significant differences ($p \leq 0.05$), influenced by both season and days after regrowth (DAR), except in autumn, where no differences were observed ($p \geq 0.05$) (Table 6). During summer, the highest values were recorded, with an average of 26.4% and a range between 12.6 and 36.0%, which was associated with greater leaf production (Table 4). Autumn followed closely, with an average of 25.9% and a range of 15 to 42%, also indicating substantial foliar production. In contrast, winter and spring presented the lowest light interception, with averages of 7.6% and 11.0%, respectively. The lowest interception values were observed at 15 DAR across all four seasons, with values of 3.4, 6.7, 12.6, and 15.0% in winter, spring, summer, and autumn, respectively. In contrast, the highest values were recorded at 90 DAR in winter and summer, while in spring they were similar at 75 and 90 DAR, and in autumn, no significant differences were found between DAR ($p \geq 0.05$). These findings align with the greater dry matter production observed at later regrowth stages in each season (Table 3), where the leaf component contributed most to the total yield (Table 4). A study by Juanes-Márquez *et al.* (2022) on the same species

Table 6. Light interception (LI%) of *Amelichloa clandestina* evaluated at different days after regrowth (DAR) in northeastern Mexico.

DAR	Winter	Spring	Summer	Autumn	SEM
15	3.4 c	6.7 b	12.6 b	15.0 a	1.96±
30	3.7 c	9.6 ab	24.0 ab	17.3 a	2.91±
45	7.5 b	9.6 ab	25.3 ab	23.0 a	2.98±
60	8.8 b	11.3 ab	28.3 ab	29.0 a	3.24±
75	10.4 ab	14.3 a	32.3 ab	29.3 a	3.06±
90	12.6 a	14.6 a	36.0 a	42.0 a	4.29±
SEM	0.83±	0.84±	2.39±	2.96±	

Means with the same letter within the same column are not significantly different (Tukey, $p \leq 0.05$). SEM: Standard error of the mean.

reported a similar seasonal pattern after implementing a manual harvest. Their data showed that light interceptions peaked in autumn, with an average of 49.2%, followed by winter with 45%. Summer and spring had lower values, at 28.5% and 21.0%, respectively. It is important to note that their study began in spring, suggesting that the increase in plant biomass over the year significantly contributed to the rise in light intercepted. These findings highlight the influence of environmental conditions on the plant's capacity to intercept light, a key factor for photosynthesis and biomass production (Mandal & Sinha, 2004). Likewise, the accumulation of biomass increases leaf density and, consequently, the canopy's ability to intercept sunlight, which is reflected in higher light interception (Bai *et al.*, 2016). Light interception serves as a sensitive indicator of changes in canopy structure and ecosystem productivity, reflecting the vegetation's adaptive response to environmental variations (Blanco-Valdés, 2019). It is closely linked to leaf density and plant architecture, which adjust according to environmental changes and management practices. Therefore, understanding the dynamics of light interception across seasons and regrowth ages is crucial for developing optimized management strategies in livestock systems, aiming to maximize photosynthetic efficiency and plant productivity. Husse *et al.* (2016) examined how mixing forage species with different leaf architectures and seasonal growth patterns affects cultivated pasture productivity. Similarly, Jagodziński *et al.* (2016) investigated seasonal variability in biomass and specific leaf area of understory herbs, reflecting life strategies adapted to seasonal light availability.

The analysis of the correlation matrix between dry matter yield (DMY), plant height (PH), and light interception percentage (LI) revealed a strong interconnection among these variables (Table 7). DMY showed significant correlations with both PH and LI, at 83% and 77%, respectively. This association suggests that the leaf-to-stem ratio in a plant is closely linked to the amount of light it receives or intercepts, potentially influencing physiological processes such as photosynthesis, growth, and vegetative development. Furthermore, the relationship between plant biomass and morphological development specifically in terms of height and diameter has been the subject of several studies, showing positive correlations. Mustafa *et al.* (2015) and Zezai *et al.* (2022) demonstrated a linear relationship between biomass and plant height. As a plant increases in height, its biomass also tends to increase, indicating that both height and diameter are critical traits for biomass accumulation. Complementarily, Cook and Stubbendieck (1986) highlighted a direct relationship between shoot diameter and its length, emphasizing that plant height is associated with increased biomass. Therefore, based on these relationships, it is possible to estimate the biomass of a

Table 7. Correlation matrix among key variables in the study of seasonal dry matter yield in *Amelichloa clandestina* grasslands in northeastern Mexico.

	DMY (kg DM ha^{-1})	PH (cm)	LI (%)
DMY (kg DM ha^{-1})	1.00*	0.83*	0.77*
PH (cm)	–	1.00*	0.69*
LI (%)	–	–	1.00*

*Significant differences at $p \leq 0.001$. DMY: Dry matter yield, PH: Plant height, LI: Light interception.

plant ecosystem using height as a predictor, providing a valuable tool for grassland analysis and management.

CONCLUSIONS

Amelichloa clandestina exhibits a greater regrowth capacity during the autumn season due to its higher dry matter accumulation. Additionally, days after regrowth significantly influenced both yield and plant morphology, optimizing height and overall structure, while altering biomass distribution among morphological components. Leaves were the main contributors to dry matter accumulation. These results demonstrate the interaction between environmental variables, growth cycles, and plant physiology in determining grassland productivity, providing valuable information for pasture management and the conservation of these ecosystems.

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