Colegio de Postgraduados

Yield of Five Alfalfa Varieties (*Medicago sativa* L.) Under Two Cutting Frequencies

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ABSTRACT

Objective: To determine the yield and morphological composition of five alfalfa varieties under two defoliation frequencies during the spring-summer period.

Design/Methodology/Approach: A randomized block design was employed, following a 5×2×2 factorial arrangements. The factors considered were five alfalfa varieties, two cutting frequencies (CF), and two seasons of the year, resulting in a total of 20 treatments with three replicates. The evaluated variables included dry matter yield (DMY), plant height, leaf-to-stem ratio (L:S), leaf area index (LAI), and morphological composition (MC). A factorial analysis was conducted using the FACTORIAL ANOVA and PROC GLM procedures, along with a mean sensitivity test via Tukey (α=0.05), utilizing the SAS statistical software.

Results: The San Miguel variety exhibited the highest DMY (2,150 kg DM ha^{-1}) and plant height (31 cm). A light CF (35 days) resulted in higher yield (1,256 kg DM ha^{-1}), greater height (29 cm), and a higher LAI (3.3), while also favoring the L:S ratio (1.07). Summer yielded higher production (2,280 kg DM ha^{-1}), whereas spring showed a higher leaf proportion (1.05). Regardless of variety and season, MC displayed a greater percentage of leaves and stems under a light cutting frequency.

Study Limitations/Implications: No limitations were identified; however, further evaluations are needed during the autumn-winter period.

Findings/Conclusions: Cutting frequency was the determining factor influencing the evaluated variables. Its interaction with the season largely defined the proportion of morphological components and overall pasture quality.

Keywords: *Medicago sativa*, dry matter, temperature, defoliation, cultivar.

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INTRODUCTION

Alfalfa (Medicago sativa L.) is the most widely used legume for the production of plant-based protein in forage crops, making it the most important forage in agricultural production systems. It is also the most utilized crop for biomass production due to its dry matter yield and nutritional quality (Rojas-García et al., 2017; Rivas et al., 2020). The time required for a cultivated species to recover the harvested biomass, whether through animal or mechanical defoliation known as the defoliation interval, recovery period, or regrowth pattern is influenced by multiple environmental factors. Among these, ambient temperature has been identified as the primary determinant of a plant's photosynthetic capacity and, consequently, its yield (Montes *et al*., 2016; Gaytán *et al*., 2019). In addition to these findings, other studies indicate that during spring and summer, climatic conditions optimally stimulate the growth and development of alfalfa plants, leading to greater biomass accumulation, increased height, a higher leaf area index (LAI), and greater stem density per tiller, all of which determine overall yield (Teixeira *et al*., 2008; Álvarez-Vázquez *et al*., 2023). Therefore, understanding the seasonal productive behavior and regrowth patterns of different alfalfa varieties cultivated in the region is essential for establishing optimal defoliation frequencies. This, in turn, enables more efficient forage production depending on the cultivated varieties (Rivas *et al*., 2020). Several studies have reported that cutting frequencies of every four to five weeks during spring and summer stimulate the formation of new stems and leaf tissue, which enhances yield, persistence, quality, and overall productivity of alfalfa pastures (Montes *et al*., 2016; Gaytán *et al*., 2019; Álvarez-Vázquez *et al*., 2023). The aim of this study was to evaluate the productive performance of five alfalfa varieties under different cutting frequency schemes during the spring-summer period. The research hypothesis proposed that the San Miguel and Oaxaca alfalfa varieties would exhibit higher yield under severe cutting frequencies during spring.

MATERIALS AND METHODS

Study area

The study was conducted during the spring-summer season of 2023 at the Instituto Tecnológico del Valle de Oaxaca (ITVO) in Xoxocotlán, Oaxaca (17° 01' 20.40" N, 96° 44' 51.50" W) at an altitude of 1,530 meters. The region has a warm semi-arid climate with summer rainfall (García, 2004). The soil exhibited a sandy loam texture with a pH of 7.5 and an organic matter content of 1.3%. Temperature and precipitation data (Figure 1) were obtained from the POWER Data Access Viewer database (NASA, 2024).

Establishment and experimental design

The establishment of the pastures took place in December 2022, using viable pure seed with an average germination rate of 92% and a seeding density of 30 kg ha^{-1}. Each

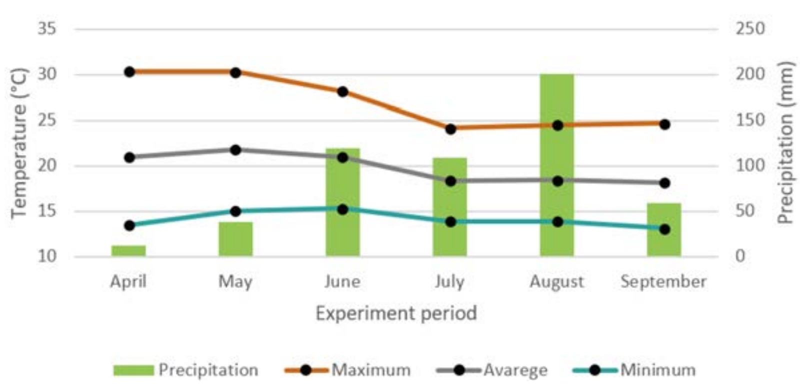

Figure 1. Maximum, average, and minimum temperature, along with monthly accumulated precipitation during spring and summer of 2023.

plot measured 42 m^2 per variety. Irrigation was applied every 15 days, and no fertilizers or agrochemicals were used for pest or weed control. A randomized block design was employed, following a 5×2×2 factorial arrangement. The factors considered were alfalfa varieties (Aragón, Atlixco, San Miguel, Victoria, and Oaxaca), two cutting frequencies (severe: every four weeks; light: every five weeks), and two seasons (spring and summer), resulting in a total of 20 treatments with three replicates.

In March, a uniformity cut was performed to minimize the residual forage covariate effect. Subsequent cuts were adjusted according to the designated cutting frequency, maintaining a residual height of 5 cm above ground level.

Variables evaluated

Height

Before each defoliation, the height of 20 plants was recorded using a measuring tape placed parallel to the plant, measuring from its base at ground level to the uppermost young vegetative tissue.

Dry matter yield (DMY)

The fixed-frame method was used, in which all the forage within a 0.25 m^2 square was harvested. The forage was then washed and weighed fresh using a scale (Model B-15, Brand: IBN). A 100 g subsample was taken and placed in a forced air drying oven (Model H-B2, Brand: Riossa) at 55 °C until a constant weight was reached to determine moisture content.

Leaf-to-stem ratio (L:S)

The leaf-to-stem ratio was estimated by dividing the dry weight of the leaves by the dry weight of the stems from the 100 g subsample.

Leaf area index (LAI)

Approximately 10% of the subsample weight was used. Leaf area was determined using the ImageJ® software, and with the obtained leaf area data and the sampled surface, the leaf area index (LAI) was estimated.

Morphological composition (MC)

A second 100 g subsample was separated and weighed by morphological components (leaf, stem, inflorescence, and dead material). Each component was placed in separate paper bags for subsequent drying.

Statistical analysis

The data obtained for the evaluated variables were grouped by cutting frequency and season. They were analyzed using Bartlett's test, considering that the data followed a normal distribution, with a significance level greater than $P<0.05$. This confirmed the normal distribution of the data, eliminating the need for transformation. Therefore, the data were used for mean analysis (Tukey, P<0.05), main effects, and interactions through the Factorial ANOVA and GLM procedures in SAS 9.0 for Windows.

RESULTS AND DISCUSSION

Forage yield

The DMY values (Table 1) indicate that the San Miguel variety outperformed Victoria by 15% (P<0.05), while no significant differences were observed among the remaining varieties (P>0.05). A light cutting frequency (CF) produced 8% more forage than a severe cut, and summer accumulated 23% more forage than spring. Studies have shown contrasting responses among varieties. Rojas-García *et al.* (2017) and Álvarez-Vázquez *et al.* (2018) reported San Miguel as the highest and lowest-yielding variety in their respective studies. Regarding cutting intervals, the results obtained with a light CF contrast with those of Álvarez-Vázquez *et al.* (2023), who found no significant differences (P>0.05) between harvesting every four or five weeks in both seasons. Conversely, Gaytán *et al.* (2019) demonstrated that cutting alfalfa every four weeks resulted in higher DMY, regardless of pasture establishment age. The light CF allowed for a longer recovery period between cuts, optimizing radiation and temperature utilization by the canopy in both seasons (Teixeira *et al.*, 2008; Hernández *et al.*, 2012). The higher summer yield aligns with findings reported by Álvarez-Vázquez *et al.* (2018), Rojas *et al.* (2019), and Rivas *et al.* (2020).

These yields may be due to the fact that during this period there are rains and warm temperatures that favor the optimal development of alfalfa (Teixeira *et al.*, 2008).

Height

La The San Miguel variety exhibited the greatest height (31 cm) among the evaluated varieties (P<0.05), with a 6 cm difference compared to Victoria, which had the shortest

Table 1. Forage dry matter yield, growth rate, height, leaf-to-stem ratio, and leaf area index under different varieties, cutting frequencies, and seasons.

Factor		DMY kg MS ha^{-1}	Height (cm)	Leaf-to-stem ratio (L:S)	LAI
Variety	Aragón	2126 ab	28 b	0.99 a	3.3 a
	Atlixco	2114 ab	28 b	1.03 a	3.2 a
	San Miguel	2150 a	31 a	1.01 a	3.2 a
	Victoria	1874 b	25 c	1.00 a	3.0 a
	Oaxaca	2100 ab	28 b	1.04 a	3.1 a
	SE	94	0.7	0.02	0.10
Frequency	Severe	1989 b	27 b	1.07 a	3.0 b
	Mild	2156 a	29 a	0.96 b	3.3 a
	SE	59	0.4	0.01	0.06
Season	Spring	1865 b	28 a	1.05 a	3.2 a
	Summer	2280 a	28 a	0.98 b	3.1 a
	SE	59	0.4	0.01	0.06

Means with the same letter in each column do not present statistical differences (P>0.05); *=(P<0.05), **=(P<0.01); NS=(P>0.05); DM=dry matter, LAI=leaf area index.

stature. However, no significant differences were observed among the remaining varieties (P>0.05). Allowing one additional week of growth resulted in a 2 cm increase compared to harvesting every four weeks (P<0.05). Seasonal variation did not significantly affect this variable (P>0.05). Sánchez *et al.* (2019) also documented slight differences in plant height among evaluated varieties. Regarding cutting frequency (CF), the results contrast with those reported by Gaytán *et al.* (2019), who recorded plant heights of 36 cm with four-week cutting intervals, as well as with Montes *et al.* (2016), who reported differences between cutting frequencies in spring. The height differences among varieties can be attributed to their genetic characteristics and environmental response (Sánchez *et al.*, 2019). The greater height observed with light cuts corresponded to harvesting plants at a more advanced phenological stage. Meanwhile, the minimal height variation between seasons could be due to an average temperature difference of only 3 °C between them (Figure 1). Under optimal conditions, growth remained constant, with temperature being the most influential environmental factor affecting this variable (Teixeira *et al.*, 2008).

Leaf-to-stem ra-tio (L:S)

No significant differences were found among the varieties (P>0.05). However, harvesting every four weeks and during the spring season resulted in a higher leaf-to-stem ratio (Table 1). Regarding cutting frequency (CF), these results contrast with those of Gaytán *et al.* (2019), who, using the Oaxaca variety, found no statistical differences between four- and five-week cutting intervals. However, their reported L:S values exceeded 2. Similarly, the findings align with those of Rojas-García *et al.* (2017), who observed no variations among varieties but did find seasonal differences under a four-week cutting frequency, though their reported values were lower than those in this study. Conversely, these results differ from Álvarez-Vázquez *et al.* (2018), who reported significant differences among varieties with four-week cuts but no seasonal differences. In contrast, Rivas *et al.* (2020) found significant differences both among varieties and between seasons, suggesting that this variable is strongly influenced by these two factors. Cutting every four weeks (>1) led to a higher leaf proportion due to the plant's age at the time of harvest. This proportion directly impacts the forage's nutritional value, which is correlated with the L:S ratio (Montes *et al.*, 2016; Gaytán *et al.*, 2019). The greater leaf presence in spring can be attributed to radiation and temperature, which enhance photosynthetic rates and accelerate leaf tissue turnover (Teixeira *et al.*, 2008).

Leaf area index (LAI)

No significant differences were observed among varieties or between seasons (P>0.05). However, implementing a light cutting frequency increased solar capture by alfalfa leaves by 10% (P<0.05). These results differ from those reported by Sánchez *et al.* (2019), where summer exhibited the highest leaf area per stem. Extending the cutting interval to five weeks increased the LAI, allowing the canopy to capture more light, thereby enhancing regrowth capacity and yield (Teixeira *et al.*, 2008; Rivas *et al.*, 2020).

Morphological composition (MC)

The Figure 2 illustrates the proportion of leaves, stems, and senescent material by variety under two cutting frequencies across the evaluated seasons. Among the varieties, Oaxaca, Atlixco, and San Miguel exhibited a higher average percentage of leaves under both cutting frequencies and seasons. With a light cut (Figure 3B), the leaf percentage was significantly higher regardless of variety or season (P<0.05). The percentage of stems was greater in summer (P<0.05), while senescent material increased in spring and under a severe cutting frequency (P<0.05). A higher leaf presence is commonly associated with four-week cutting intervals (Álvarez-Vázquez *et al.*, 2018). However, these results contrast with previous findings, as a five-week cutting interval allowed the varieties to recover more effectively, facilitating efficient mobilization of stored nitrogen and carbohydrates from the crown and roots (Teixeira *et al.*, 2008). No significant seasonal differences were observed in leaf proportion, consistent with the findings of Rojas *et al.* (2019).

Stem presence was higher in summer and under a light cutting frequency, which was reflected in the DMY. As cutting frequency increased, the stem percentage in the morphological composition also increased. Although the Oaxaca variety is considered the local landrace of the region, San Miguel demonstrated superior parameters in this experiment. Therefore, it could serve as a viable production alternative for farmers. This finding supports the need for further evaluation of this variety on a larger cultivation scale, allowing for direct comparisons with the local landrace in terms of actual production.

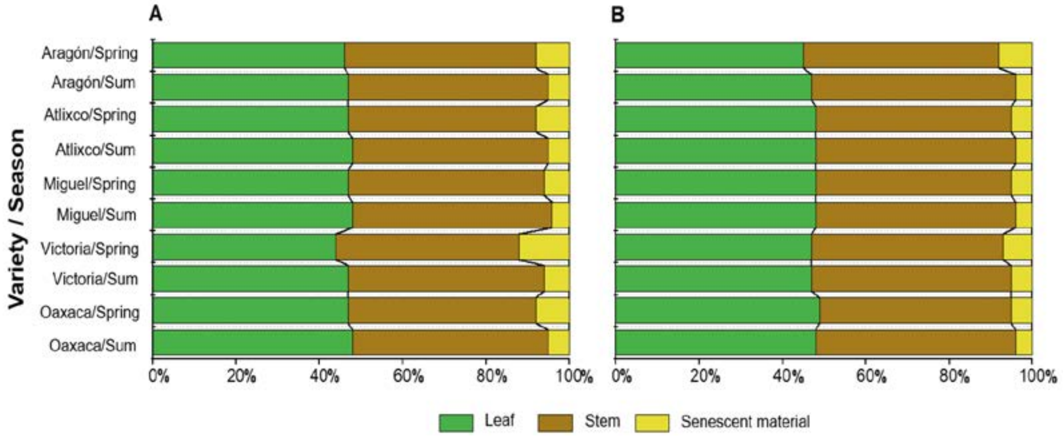

Figure 2. Changes in the morphological composition (%) of five alfalfa varieties. A=Severe CF, B=Light CF. Spr=Spring, Sum=Summer.

CONCLUSIONS

Cutting frequency was the key factor influencing the behavior of the studied variables. Its interaction with the season significantly affected the proportion of morphological components and overall pasture quality. The differences among varieties were attributed to their response to the site's edaphoclimatic conditions.

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