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Seasonal dry matter yield in three forage species

Fuentes-Huerta, A. Emmanuel[1]; Álvarez-Vázquez, Perpetuo[2*]; García-López, J. Israel[2]; Ventura-Ríos, Joel[2]; Rojas-Garcia, A. Rafael[3]; Quintanilla-Medina, J. Jeu[4]

[1] Universidad Autónoma Agraria Antonio Narro Unidad Laguna, Posgrado en Producción Agropecuario. Periférico Raúl López Sánchez, Valle Verde, Torreón, Coahuila, México. C. P. 27054.
[2] Universidad Autónoma Agraria Antonio Narro, Calzada Antonio Narro 1923, Buenavista, Saltillo, Coahuila, México. C. P. 25315.
[3] Universidad Autónoma de Guerrero.Facultad de Medicina Veterinaria y Zootecnia No. 2. Cuajinicuilapa, Guerrero, México, C. P. 41940.
[4] Facultad de Ingeniería y Ciencias, Universidad Autónoma de Tamaulipas.
* Correspondence: perpetuo.alvarezv@uaaan.edu.mx

ABSTRACT

Objective: To assess the seasonal dry matter yield of three forage species white clover (*Trifolium repens* L.), sheepgrass (*Dactylis glomerata* L.), and perennial ryegrass (*Lolium perenne* L.) under the specific edaphoclimatic conditions of southeastern Coahuila, Mexico.

Design/Methodology/Approach: Dry matter yield (DMY), morphological components, leaf-to-stem ratio (L:S), and plant height (PH) were evaluated using a completely randomized block design with three replications. The factors analyzed included season, species, and their interaction. Mean comparisons were performed using Tukey's test (α=0.05).

Results: The highest average DMY was observed in spring, reaching 4,813 kg DM ha^{-1} ($p<0.05$). Leaves were the predominant contributor to total yield, averaging 2,848 kg DM ha^{-1} and accounting for 59% of the biomass. The lowest L:S ratio occurred in summer (17), while sheepgrass exhibited the highest species-specific L:S ratio at 47 ($p<0.05$). The greatest plant heights during summer were recorded in perennial ryegrass and sheepgrass, measuring 54 cm and 21 cm, respectively.

Study Limitations/Implications: This study was conducted in northeastern Coahuila, Mexico, under drip irrigation. As such, results may vary under different climatic conditions and irrigation systems, warranting further investigation.

Findings/Conclusions: The optimal performance of all three forage species was achieved during spring, with no single cultivar outperforming the others. Notably, the leaf component made the greatest contribution to total yield across all species.

Keywords: *Dactylis glomeratha* L., *Lolium perenne* L., *Trifolium repens* L., dry matter yield, botanical and morphological composition.

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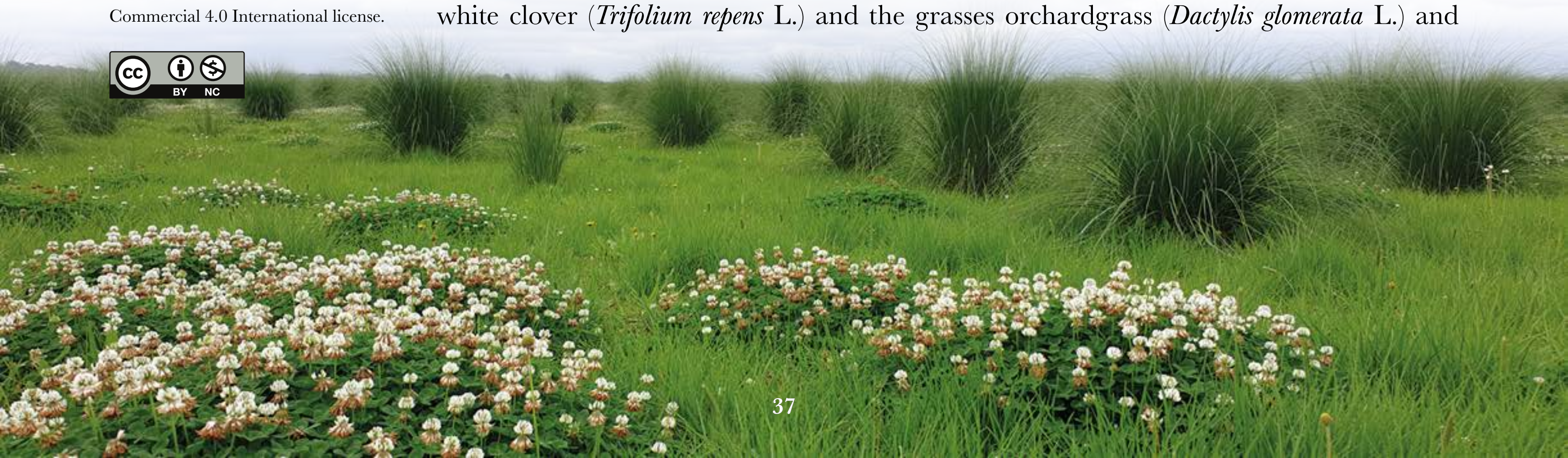
INTRODUCTION

Grasses and legumes form the foundation of forage-based grazing systems (Rojas *et al.*, 2017). Among the most commonly used forage species in these systems are the legume white clover (*Trifolium repens* L.) and the grasses orchardgrass (*Dactylis glomerata* L.) and



perennial ryegrass (*Lolium perenne* L.) (Sanderson *et al.*, 2013). Although monocultures exhibit pronounced seasonality, the integration of legumes with grasses mitigates this effect (Rojas-García *et al.*, 2016). The highest dry matter yields in forage species typically occur during seasons characterized by greater moisture availability, elevated temperatures, and increased solar radiation —namely, spring and summer (Maldonado-Peralta *et al.*, 2017). Consequently, understanding the growth dynamics of these forage species across various zones and regions is essential, given that both annual and seasonal biomass production are subject to fluctuations driven by physiological and morphological changes (Durand *et al.*, 1999). Therefore, evaluations must be grounded in species-specific growth patterns and phenological stages, as well as in the diverse edaphoclimatic conditions of each region, to optimize pasture quality, productivity, and persistence (Castro *et al.*, 2011). In this context, the aim of the present study was to analyze the dry matter yield of white clover, orchardgrass, and perennial ryegrass under the climatic conditions of southeastern Coahuila, Mexico.

MATERIALS AND METHODS

The experimental site is located in southeastern Saltillo, Coahuila, Mexico, at the Universidad Autónoma Agraria Antonio Narro, situated at 25° 23' 59" N latitude and 101° 59' 17" W longitude, at an altitude of 1,783 meters. The average maximum monthly temperature reaches 34 °C in May, while the minimum drops to −4 °C in February (Figure 1). The soil in the region is classified as sandy clay loam with a pH of 7.3. The natural physical environment is characterized as temperate semi-arid, with an annual precipitation ranging from 300 to 400 mm.

White clover (*Trifolium repens* L.), orchardgrass (*Dactylis glomerata* L.), and perennial ryegrass (*Lolium perenne* L.) pastures were established on February 19, 2021, at seeding rates of 5, 20, and 10 kg of viable pure seed per hectare, respectively, within a 448 m^2 experimental area. This area was divided into nine 25 m^2 plots (5×5 m) using a completely randomized block design with three replications. The treatments included cultivar, season, and their interaction. At the beginning of the summer 2021 season, a uniformity

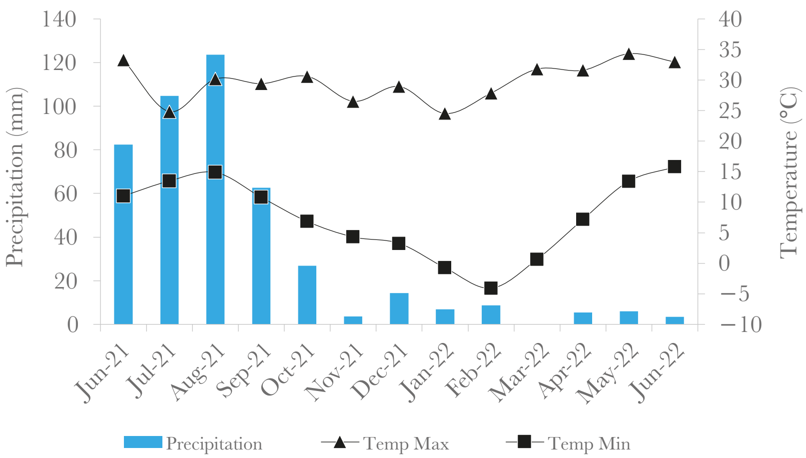


Figure 1. Monthly distribution of accumulated precipitation, maximum, and minimum temperatures recorded during the experimental period (Red Universitaria de Observatorios Atmosféricos–RUOA, UAAAN).

cut was made at 5 cm above ground level to homogenize the cultivars and initiate the study. Subsequent cuts were performed manually at 5 cm above the soil surface, adjusted according to the season: every 28 days during spring and summer, every 35 days in autumn, and every 42 days in winter. Irrigation was applied every 14 days at field capacity using a drip irrigation system equipped with 6000-gauge tape, with emitters spaced 10 cm apart and 50 cm between drip lines. The evaluated variables included dry matter yield (DMY), morphological-botanical composition (percentage and DMY), leaf-to-stem ratio (L:S), and plant height. For yield estimation, forage was harvested from two randomly placed 0.25 m^2 quadrants per plot. The samples were placed in paper bags and oven-dried to a constant weight in a forced-air oven (model POM-246F) at 55 °C for 72 hours. Morphological-botanical composition was determined from approximately 10% of the harvested sample and separated into leaf, petiole, stolon (legume), stem, dead material, inflorescence (morphological components), and weeds (botanical component). The leaf and stem components were used to calculate the L:S ratio by dividing leaf mass by stem mass. Plant height was measured prior to cutting, using 15 random measurements per plot with a 100 cm graduated wooden ruler. To evaluate the effects of cultivar and season, an analysis of variance (ANOVA) was conducted using the PROC GLM procedure in SAS (SAS, 2019), based on a randomized block design. Mean comparisons were performed using Tukey's test ($\alpha=0.05$). Prior to ANOVA, Bartlett's test for homogeneity of variances was applied, confirming the assumptions of normality and homogeneity.

RESULTS AND DISCUSSION

Significant effects were observed for the main factor season (S) and its interaction with cultivar (C) on dry matter yield (DMY) and plant height (PH), except for the leaf-to-stem ratio (L:S). Specifically, the season (S) and the season × cultivar (S×C) interaction showed significant differences ($p<0.05$) in DMY and PH. In contrast, cultivar alone had a significant effect only on plant height. The L:S ratio did not show statistically significant differences for any of the evaluated factors (Table 1).

In the mean comparison of main factors, spring and summer stood out statistically for both dry matter yield (DMY) and plant height (PH) ($p<0.05$), with values of 4,813 and 3,749 kg DM ha^{-1}, and 22 and 27 cm, respectively. No significant seasonal effect

Table 1. Mean squares from the evaluation of white clover (*Trifolium repens* L.), orchardgrass (*Dactylis glomerata* L.), and perennial ryegrass (*Lolium perenne* L.) in southeastern Coahuila, Mexico.

Source of Variation	df	DMY (kg DM ha^{-1})	PH (cm)	L:S Ratio
Season (S)	3	2023*	536*	472
Cultivar (C)	2	1781	1851*	472
S×C	6	3940*	202*	344
CV (%)	–	33	12	72

*CV: Coefficient of variation; S×C: Season×Cultivar interaction; df: degrees of freedom; DMY: Dry matter yield; PH: Plant height; L:S: Leaf-to-stem ratio; : Significant differences ($P\leq0.05$).

was observed on the leaf-to-stem ratio (L:S) ($p>0.05$). Regarding the cultivar factor, there were no significant differences in DMY ($p>0.05$). However, for PH, perennial ryegrass (PR) and orchardgrass (OG) recorded the highest values, while white clover (WC) had the lowest. In contrast, for the L:S ratio, the highest value was observed in OG (47), compared to lower values in PR and WC, which registered 17 and 11, respectively ($p<0.05$). The seasonal trend in DMY followed a descending pattern: spring>summer>winter>autumn ($p<0.05$) (Table 2). These findings confirm that seasonal climatic variations influence the physiological processes and overall performance of forage species (Zaka *et al.*, 2017). Zebadúa *et al.* (2001) noted that greater dry matter accumulation in grasses such as orchardgrass tends to occur in spring and summer compared to autumn and winter. Similarly, other studies have reported higher yields during spring and summer due to elevated temperatures and higher relative humidity (Rojas-García *et al.*, 2016). Conversely, lower temperatures lead to reduced growth rates, thereby limiting forage accumulation (Rojas *et al.*, 2016). As a result, environmental conditions during autumn and winter were not favorable, as these periods were marked by significant temperature drops and frost events, which negatively impacted pasture performance.

Table 3 presents the seasonal changes in the botanical and morphological structure of the pasture throughout the year. Leaf was the predominant component contributing to total forage yield, with 2,848 kg DM ha^{-1} in spring, accounting for approximately 59% of total yield. However, no statistical differences were found among cultivars ($p>0.05$), with an overall average of 1,755 kg DM ha^{-1}. Petiole, evaluated only in the legume white clover (*Trifolium repens* L.), showed its highest yield in spring with 678 kg DM ha^{-1}, with similar results for stolon, although without statistically significant differences across seasons ($p>0.05$). Regarding stem yield, spring and summer stood out with 378 and 434 kg DM ha^{-1}, respectively, surpassing autumn and winter, which registered 100 and 41 kg DM ha^{-1} ($p<0.05$). Among cultivars, perennial ryegrass produced significantly more

Table 2. Mean comparison of evaluated factors in white clover (*Trifolium repens* L.), orchardgrass (*Dactylis glomerata* L.), and perennial ryegrass (*Lolium perenne* L.) in southeastern Coahuila, Mexico.

Variation Factor	DMY (kg DM ha^{-1})	PH (cm)	L:S Ratio
Evaluation Season			
Summer	3,749 a	27 a	17 a
Autumn	1,654 b	12 b	27 a
Winter	1,955 b	11 b	34 a
Spring	4,813 a	22 a	21 a
Cultivars			
WC (White Clover)	3,476 a	8 b	17 b
OG (Orchardgrass)	2,738 a	16 a	47 a
PR (Perennial Ryegrass)	2,914 a	32 a	11 b

Means within the same column followed by the same lowercase letter are not significantly different (Tukey; $p>0.05$). WC=White clover; OG=Orchardgrass; PR=Perennial ryegrass.

Table 3. Comparison of means of the factors evaluated in botanical-morphological components (kg DM ha^{-1}) of white clover (*Trifolium repens* L.), orchardgrass (*Dactylis glomerata* L.) and perennial ryegrass (*Lolium perenne* L.) in southeastern Coahuila, Mexico.

Factor	Leaf	Petiole	Stolon	Stem	Dead Material	Inflorescence	Weeds
Season							
Summer (S)	1812 b	170 b	54 a	434 a	511 a	357 a	410 a
Autumn (A)	1151 b	90 b	30 a	100 b	152 b	37 b	92 b
Winter (W)	1209 b	155 b	27 a	41 b	421 a	6 b	107 b
Spring (Sp)	2848 a	678 a	78 a	378 a	406 a	226 a	113 b
Cultivar							
WC (White Clover)	1679 a	820	142	*	310 b	58 b	99 b
OG (Orchardgrass)	2028 a	*	*	112 b	556 a	--	6 b
PR (Perennial Ryegrass)	1559 a	*	*	603 a	253 b	407 a	437 a

*Means within the same factor and column followed by the same lowercase letter are not significantly different (Tukey; $p \leq 0.05$). S=Summer, A=Autumn, W=Winter, Sp=Spring; WC=White Clover, OG=Orchardgrass, PR=Perennial Ryegrass. *=Component not present in the pasture; --=Not applicable.

stem biomass than orchardgrass, with 603 and 112 kg DM ha^{-1}, respectively ($p<0.05$). For dead material, autumn recorded the lowest value with only 152 kg DM ha^{-1}, while the other seasons ranged from 406 kg DM ha^{-1} in spring to 511 kg DM ha ¹ in summer ($p<0.05$). Among cultivars, orchardgrass had the highest amount of dead material at 556 kg DM ha^{-1}, followed by white clover (310 kg DM ha^{-1}) and perennial ryegrass (253 kg DM ha^{-1}) ($p<0.05$).

Inflorescence production followed a trend similar to stem yield, indicating that increased growth is associated with flowering. Summer and spring recorded the highest values 357 and 226 kg DM ha^{-1}, respectively while autumn and winter had the lowest, with 37 and 6 kg DM ha^{-1}. Perennial ryegrass exhibited the highest inflorescence production at 407 kg DM ha^{-1}. As for the botanical component of weeds, the highest values were observed in summer, particularly in the perennial ryegrass plots, with 410 and 437 kg DM ha^{-1}, respectively. In contrast, autumn, winter, and spring, along with white clover and orchardgrass cultivars, recorded lower weed biomass, with no significant differences among them ($p>0.05$). These results underscore that a higher leaf proportion reflects superior forage quality, as leaves are the most palatable and nutrient-rich part of the plant due to their high crude protein content and digestibility (Castro *et al.*, 2012). Perennial ryegrass showed the highest stem yield, attributed to its growth habit being taller and more erect than orchardgrass and white clover. The greater presence of inflorescences in perennial ryegrass also indicates a faster growth and maturation rate compared to the other cultivars. González-Hernández *et al.* (2005) noted that stems and inflorescences are most prevalent in spring, when plants enter the reproductive phase. Similarly, Mendoza *et al.* (2018) reported that certain morphological components are influenced by higher temperatures, which favor forage growth. In contrast, González-Hernández *et al.* (2005) also noted that during winter, weeds tend to contribute more to total biomass, as desirable species exhibit limited growth.

To evaluate the leaf-to-stem weight ratio (L:S), the relationship between leaf and stem biomass was assessed for white clover (*Trifolium repens* L.), orchardgrass (*Dactylis glomerata* L.), and perennial ryegrass (*Lolium perenne* L.) under the environmental conditions of northeastern Coahuila, Mexico (Table 4). Significant differences were observed between cultivars and seasons ($p<0.05$), except during winter, where no statistical differences were found ($p>0.05$).

Among cultivars, orchardgrass recorded the highest average L:S ratio at 47, significantly outperforming white clover and perennial ryegrass ($p<0.05$). Regarding seasonal averages, autumn (27), winter (34), and spring (21) had higher L:S ratios compared to summer, which showed the lowest value at 17 ($p<0.05$). When comparing cultivars within each season, orchardgrass consistently had the highest L:S ratios across all seasons, with values of 41, 62, 42, and 42 in summer, autumn, winter, and spring, respectively. The lowest L:S values in spring and summer were observed in perennial ryegrass, both registering 2. In autumn, perennial ryegrass had a value of 7, which was not significantly different from that of white clover (12) ($p>0.05$). Seasonally, the highest L:S ratios were found in winter, likely due to limited stem development during the first four weeks of regrowth (Esparza *et al.*, 2009). According to Sheaffer et al. (2000), another factor influencing the L:S ratio is the regrowth age of the species. During the vegetative phase, leaf production is dominant; however, as the plant matures, stem elongation increases, ultimately surpassing the leaf fraction in the total plant biomass.

Pasture growth, expressed as plant height and measured using two methods ruler (RM) and rising plate meter (PM) is presented in Table 5. Significant differences were observed between cultivars and seasons ($p<0.05$). For both methods, the highest average plant height among cultivars was recorded in perennial ryegrass, with 32 cm and 8 cm using RM and PM, respectively. The lowest heights using the ruler method were recorded in white clover (7 cm), while for the plate method, both white clover and orchardgrass had the lowest values at 4 cm. Seasonally, the tallest plants were measured in summer and spring using RM, at 27 and 22 cm, respectively. With PM, the highest value was recorded in spring (7 cm). In contrast, autumn and winter yielded the lowest plant heights using RM, and winter was the lowest with PM. When

Table 4. Leaf-to-stem ratio of white clover (*Trifolium repens* L.), orchardgrass (*Dactylis glomerata* L.), and perennial ryegrass (*Lolium perenne* L.) during the production cycle from June 2021 to May 2022 in southeastern Coahuila, Mexico.

Cultivar	Summer (S)	Autumn (A)	Winter (W)	Spring (Sp)	Mean ($\bar{x}$)	SEM
White Clover (WC)	10 ab	12 b	27 a	20 ab	17 b	7
Orchardgrass (OG)	41 a	62 a	42 a	42 a	47 a	25
Perennial Ryegrass (PR)	2 b	7 b	33 a	2 b	11 b	3
Mean ($\bar{x}$)	17 B	27 A	34 A	21 A	25	
SEM	7.4	22	29	9		

Means followed by the same lowercase letter in a column and uppercase letter in a row are not statistically different (Tukey; $p>0.05$). SEM=Standard Error of the Mean. WC=White Clover; OG=Orchardgrass; PR=Perennial Ryegrass.

Table 5. Plant height of white clover (*Trifolium repens* L.), orchardgrass (*Dactylis glomerata* L.), and perennial ryegrass (*Lolium perenne* L.) in southeastern Coahuila, estimated using the ruler and plate methods.

Cultivar	Summer (S)	Autumn (A)	Winter (W)	Spring (Sp)	Mean ($\bar{x}$)	SEM
Ruler Method (RM)						
White Clover (WC)	6 c	5 c	6 b	12 b	7 c	1.0
Orchardgrass (OG)	21 b	11 b	10 b	20 b	15 b	1.0
Perennial Ryegrass (PR)	54 a	21 a	18 a	35 a	32 a	2.0
Mean ($\bar{x}$)	27 A	12 B	11 B	22 A	18	
SEM	1.0	1.0	1.0	4.0		
Plate Method (PM)						
White Clover (WC)	3 b	2 a	3 b	7 a	4 b	1.0
Orchardgrass (OG)	6 b	3 a	3 b	5 a	4 b	0.4
Perennial Ryegrass (PR)	10 a	4 a	7 a	10 a	8 a	0.9
Mean ($\bar{x}$)	6 AB	3 B	4 AB	7 A	5	
SEM	1.0	1.0	–	2.0		

Means with the same lowercase letter in a column and uppercase letter in a row are not statistically different (Tukey; $p>0.05$). SEM=Standard Error of the Mean. TB=White Clover, PO=Orchardgrass, BP=Perennial Ryegrass.

comparing cultivars within each season, perennial ryegrass consistently outperformed the others using RM, with plant heights of 54, 21, 18, and 35 cm in summer, autumn, winter, and spring, respectively. White clover registered the shortest plants at 6, 5, 6, and 12 cm for the same seasons. However, in winter, white clover and orchardgrass showed no significant difference ($p>0.05$). In contrast, with PM, perennial ryegrass again showed the highest plant height in all seasons 10, 4, 7, and 10 cm but without significant differences in autumn and spring ($p>0.05$). In summer and winter, white clover and orchardgrass showed significantly lower growth ($p<0.05$), a trend reflected in the overall cultivar averages. According to Rojas *et al.* (2016a), the greatest plant heights are typically observed in summer and spring, seasons characterized by optimal temperature and humidity conditions for plant growth. Similarly, Flores *et al.* (2015) noted that the highest dry matter yields align with the tallest plant heights observed in these seasons. Castro *et al.* (2012) emphasized that plant height in pastures is effectively correlated with forage production and intercepted radiation. Therefore, plant height is considered an indirect but practical indicator for estimating dry matter production and serves as a valuable tool for efficiently managing grass-legume mixtures, ultimately optimizing production costs (Adams *et al.*, 1977). Furthermore, Rojas-García *et al.* (2021) stated that plant height measured with the rising plate meter shows a similar trend to the ruler method, though the plate method consistently records lower values due to forage compression by the plate. Supporting this, Mendoza-Pedroza *et al.* (2021) highlighted the utility of the plate method as a reliable tool for estimating real-time standing biomass in the field.

CONCLUSIONS

The edaphoclimatic conditions of southeastern Coahuila do not adversely affect the forage production of white clover (*Trifolium repens* L.), orchardgrass (*Dactylis glomerata* L.), and perennial ryegrass (*Lolium perenne* L.). However, the seasonal factor proved significant, with spring and summer showing the highest dry matter yields. These seasons also exhibited greater plant height and a higher contribution of leaf biomass to total forage yield.

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