Scientific Electronic Archives
Issue ID: Sci. Elec. Arch. Vol. 17 (2)
March/April 2024
DOI: http://dx.doi.org/10.36560/17220241901
Article link: https://sea.ufr.edu.br/SEA/article/view/1901

ISSN 2316-9281

Stubble height impact on forage accumulation and nutritive values in native meadows

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Abstract. Forage from native prairie meadows is an important feed source in Eastern Kansas to address the challenges of shallow, acidic, and nutrient-poor soils. However, it is crucial to establish an optimal stubble height to optimize forage accumulation (FA) and nutritive value (NV). Our objective was to evaluate the impact of stubble height on FA and NV in native prairie meadows in Eastern Kansas. The study was conducted in native meadows using a randomized complete block with three replications across three locations (Parsons, Caney, and Coyville, all located in Eastern Kansas). Treatments were four stubble heights (2.5, 7.5, 12.5, and 17.5 cm). Shorter stubble height resulted in greater FA, as it removes a greater proportion of the forage accumulated. Forage accumulation was slightly higher when harvested at 7.5- than at 12.5-cm stubble height. Crude protein content increased from 2.5- to 17.5-cm stubble height with no differences between 7.5- to 12.5-cm stubble height. The opposite pattern of CP occurred for CPA (Table 3), with only 25 kg in difference from 7.5- to 12.5-cm stubble height. Stubble height did not affect fiber content (NDF and ADF) and energy content (TDN, NEL, NEG, and NEM). Thus, stubble height from 7.5 to 12.5 cm provides great FA and CPA in native prairie meadows. However, to ensure long stand life and better CP content, stubble height above 12.5 cm should be preferred, which may contribute to reducing animal supplementation costs.
Keywords: Forage quality, forage production, harvesting intensity, native prairie

Introduction

Beef cattle production in the Midwest United States is based on cool-season forage species that concentrate forage accumulation in the spring and early summer (MOORE et al., 2004), or in fall stockpiled forage (YASUOKA et al., 2023). In addition, areas with shallow, acid, and nutrient-poor soils (KEYSER, 2023) are common in Eastern Kansas. In these areas, native meadows provide forage, when cool-season forage species, such as tall fescue (*Festuca arundinacea* Schreb.), reduce growth during the summer (FOSTER et al., 2009).

A key decision in pasture management is to determine harvesting intensity. Leaves are the most active photosynthetic tissues (TAIZ et al., 2015) and, consequently, play a primary role in plant growth (COÊLHO et al., 2013). Thus, greater forage accumulation (FA) is expected with greater stubble height because the residual leaf area index (LAI) will be greater (GATES; HILL; BURTON, 1999). Simultaneously, leaves are the most valuable plant tissue to feed animals, leading to a trade-off between residual LAI for plant growth and leaf harvest for animal performance (RAYBURN; GRIGGS, 2020). Brougham (1956), studying the optimal defoliation moment, suggested that the residual LAI should be enough to intercept all solar radiation to maintain the FA rate close to the maximum value.

Stubble height also affects the forage nutritive value (NV), as leaves are more abundant in the upper canopy strata, while stem and dead material are concentrated closer to the ground (TESK et al., 2020). Leaf proportion, which has lower fiber and higher protein content, in the harvested forage will be directly affected by the stubble height (COÊLHO et al., 2013). The shorter the stubble height, the greater the participation of stem and dead material in the forage mass, negatively impacting nutritive value.

In Eastern Kansas, producers usually harvest native meadows at 7.5 cm stubble height or lower. However, considering the impact of stubble height on the agronomic performance of forage species, we hypothesized that a lower defoliation intensity improves forage nutritive value without a great reduction in FA. Our objective was to evaluate the impact of stubble height on FA and NV of native meadows in Eastern Kansas.

Material and Methods

The study was conducted in native meadows at three locations in Southeast Kansas: at the Southeast Research and Extension Center in Parsons (37º22'N, -95º17'W), and on two farms located in Caney (37º02'N, -95º92'W), and Coyville (37º40'N, -95º53'W). The experiment was carried out for two years in Parsons (defined as Parsons 1 and Parsons 2), and for one year in Caney and Coyville. The climate in all locations according to Köppen is a humid subtropical climate, characterized by hot and humid summers, and mild to cool winters (PEEL; FINLAYSON; MCMAHON, 2007). The weather data for the experimental period were recorded at the Mesonet weather stations (PATRIGNANI et al., 2020) located 0.5, 31.4, and 23.2 km from the experimental areas of Parsons, Caney, and Coyville, respectively (Table 1). The soil type in all locations is a Parsons loam (fine Albaqualfs molic, mixed, active, thermal). The soil chemical analyses were taken in each field from 0-15 cm soil samples (Table 2). No fertilization or lime was applied in these locations, as it is not recommended for native prairies due to the lack of response.

Table 1. Monthly rainfall and maximum and minimum temperatures at Parsons, Caney, and Coyville, KS during the experimental period.

Weather variable	2021						2022					
	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
						Parsons 1						
Max. Temp. (ºC)	31	31	30	22	15	15	6	6	15	20	24	30
Min. Temp. (ºC)	20	21	16	10	2	2	-5	-4	2	7	14	19
Rainfall (mm)	238	89	81	105	13	31	1	15	86	52	230	136
						Caney						
Max. Temp. (ºC)	31	32	32	24	17	16	9	9	16	21	25	30
Min. Temp. (ºC)	20	21	17	10	3	1	-6	-6	2	8	14	19
Rainfall (mm)	75	13	122	25	85	105	2	32	80	28	205	87
						Coyville						
Max. Temp. (ºC)	30	31	29	23	16	15	7	8	15	20	24	30
Min. Temp. (ºC)	20	21	17	10	3	1	-7	-6	1	7	14	19
Rainfall (mm)	145	59	129	97	28	8	2	12	93	70	207	58
	2022						2023					
	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
						Parsons 2						
Max. Temp. (ºC)	35	35	31	23	13	7	9	11	13	21	25	30
Min. Temp. (ºC)	22	20	15	8	1	-3	-2	-1	2	6	13	18
Rainfall (mm)	22	20	13	61	79	55	50	52	24	28	188	98

Table 2. Soil chemical characteristics in the experimental area in three locations in Southeast Kansas.

Location	pH	Phosphorus (ppm)	Potassium (ppm)
Parsons	5.2	2.4	61.0
Caney	5.8	2.1	26.6
Coyville	5.8	1.1	25.9

The experimental design for all sites was a randomized complete block with three replications, totaling 12 experimental units of 9 by 3 m each. Treatments were four stubble heights (2.5, 7.5, 12.5, and 17.5 cm).

In July 2021, the experimental area in all locations was mowed to a 7.5-cm stubble height, and the experimental period began. The experimental period in Parsons was from July 2021 to 8 July 2022 (Parsons 1) and from 9 July 2022 to 3 July 2023 (Parsons 2). In Caney and Coyville, the experimental period was from July 2021 to 8 July 2022.

In Parsons 1 and Caney, Coyville, FA was estimated by sampling all forage inside two quadrats (0.5 × 1.0 cm) per plot at their respective stubble height (2.5, 7.5, 12.5, and 17.5 cm). In Parsons 2, FA was quantified by sampling a 0.9 by 3 m area in each plot using a flail harvester (Carter®) at the same stubble heights. The forage collected by the harvester was weighed fresh, and a subsample of ~250 g was taken and weighed. The samples collected in Parsons 1, Caney, and Coyville and the subsamples in Parsons 2 were dried at 55ºC in a forced-draft oven to constant weight and weighed. These dry samples were ground to 1 mm using a Wiley mill to determine crude protein (CP; AOAC, 2016; Method 976.06), acid detergent fiber (ADF; Ankom Technology, 2006a; Method 5), neutral detergent fiber (NDF; Ankom Technology, 2006b; Method 6), net energy lactation (NEL), and net energy gain (NEG), and net energy maintenance (NEM) (NRC, 1989). Total digestible nutrients (TDN) were estimated according to NRC (1989), and crude protein accumulation (CPA) was determined by multiplying FA and CP. Samplings were performed on 8 July 2022 and 3 July 2023 in Parsons, and on 5 July 2022 in Caney and Coyville.

Statistical analysis

The data were analyzed using a mixed-models method with a parametric structure in the covariance matrix through the MIXED procedure of SAS 9.4 (LITTELL et al., 2006). Data were analyzed in the four sites (Caney, Coyville, Parsons 1, and Parsons 2). Block and site were considered as random effects and stubble height was a fixed effect. Linear predictor and quantile-quantile plots of the residues were used to verify the homogeneity of variance and error normality. The Akaike information criterion was used to choose the covariance matrix (WOLFINGER, 1993), and the denominator degrees of freedom were corrected using the method of Satterthwaite (SATTERTHWAITE, 1946). The least square means were used to compute the means of the fixed effects and comparisons were performed using the probability of the difference of the t-test ($P < 0.05$).

Ethical principles and good practices in experimentation. This work did not involve human or animal experimentation.

Results and discussion

Forage accumulation was affected by stubble height ($P<0.01$). As the stubble height decreased, FA increased, with the 2.5-cm stubble height resulting in a 155% higher FA than the 17.5-cm stubble height (Table 3). This result highlights the impact of defoliation intensity on FA. Leaves are the main photosynthetic tissue in plants (TAIZ et al., 2015), and the stubble height has a direct impact on the remaining leaf mass after harvest (COÊLHO et al., 2013). Consequently, with higher defoliation intensity (i.e., shorter stubble height), less solar radiation is intercepted (BROUGHAM, 1956) and initial forage regrowth is lower (RAYBURN; GRIGGS, 2020).

Table 3. Forage accumulation, crude protein content, and crude protein accumulation of native meadows in three locations in Southeast Kansas.

Stubble height	Forage accumulation	Crude protein	Crude protein accumulation
cm	kg DM/ha/yr	g/kg DM	kg CP/ha/yr
2.5	3990 a	67.0 c	239 a
7.5	2380 b	68.1 bc	166 b
12.5	1925 c	74.6 ab	141 c
17.5	1565 d	74.1 a	120 d
SEM[1]	723.2	3.74	45.4

[1]SEM, standard error of the mean.

As native prairie meadows are only harvested once a year, plants may have enough time to intercept most of the sunlight and accumulate a reasonable amount of forage in the next spring, even with a relatively low initial growth rate in the shortest stubble heights in the fall. Additionally, when the canopy is harvested short, plants use their soluble carbohydrates to regrowth, and if the rest period is insufficient for replenishment of these carbohydrates, pasture persistence is affected (FULKERSON; DONAGHY, 2001). So, in the long term, shorter stubble heights can impact the carbohydrate replenishment potential in late summer, as native warm-season grasses will become dormant in the fall.

Forage accumulation was only 455 kg lower in the 12.5-cm stubble height when compared to the 7.5-cm stubble height. Although it slightly impacts FA, plants managed with taller stubble heights will reach the maximum light interception earlier (BROUGHAM, 1956), allowing plants to produce and store the carbohydrates needed to overwinter. It can contribute to reducing the fall weed competition and increase stand life.

On the other hand, although CP content was affected by stubble height ($P=0.03$), 7.5- and 12.5-cm stubble height had similar CP values. The CP response is the opposite of that in FA, with the 2.5-cm and 17.5-cm stubble heights showing the lowest and highest CP values, respectively (Table 3). As leaves have the most nutritive plant tissues (BURTON; KNOX; BEARDSLEY, 1964), plant-part composition affected forage NV (CHAPMAN; LEE; WAGHORN, 2014). As stem and dead material proportions increase from the upper to the lower canopy stratum (HODGSON, 1990), shorter stubble heights increase the presence of stem and dead material in the forage reducing CP content.

Crude protein accumulation was affected by stubble height (*P*<0.01). Similar to FA, CPA increased as stubble height decreased, doubling the CPA from 2.5- to 17.5-cm stubble height (Table 3), but only reducing on 25 kg from 7.5- to 12.5-cm stubble height. Despite the greater CP in the tallest stubble height, the shorter stubble heights resulted in greater CPA values due to the greater FA (Table 3). However, 2.5- and 7.5-cm stubble heights resulted in CP values below 70 g/kg DM (67.0 and 68.1 g/kg DM, respectively), which is the minimum recommended for proper dietary maintenance of a rumen (NRC, 2001).

Stubble height did not affect NDF (*P*=0.42), ADF (*P*=0.17), NEL (*P*=0.19), NEG (*P*=0.21), NEM (*P*=0.13), and TDN (*P*=0.17), with average values of 652 g/kg.DM (SEM=28.7), 433 g/kg.DM (SEM=17.8), 4.11 MJ/kg (SEM=0.312), 1.05 MJ/kg (SEM=0.431), 3.45 MJ/kg (SEM=0.645), and 448 g/kg.DM (SEM=3.1), respectively. The results of the present study indicate that stubble height had a minimal impact on the fiber and energy contents in native meadows.

Conclusion

In native meadow meadows, forage CP content is greater with taller stubble height, but FA and CPA will be lower. Stubble height does not have an impact on fiber (NDF and ADF) and energy content (TDN, NEL, NEG, and NEM). Stubble heights above 12.5 cm would be recommended due to the great FA and CPA with higher CP content. Ultimately, it will ensure long stand life and contribute to reducing costs associated with protein supplementation for the cattle.

Acknowledgment

This work was supported by Montgomery and Wilson County Conservation districts; the U.S. Department of Agriculture National Institute of Food and Agriculture, Hatch project 1003478; and the K-State Research and Extension Wildcat Extension District.

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