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Management strategies to improve forage accumulation and nutritive value in crabgrass hayfields

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Abstract

Crabgrass (*Digitaria spp.*) is an annual summer grass capable of self-reseeding and can provide forage with high nutritive value. However, knowledge is still limited about crabgrass management. Our objective was to compare the forage accumulation (FA) and nutritive value of two crabgrass varieties (Mojo and Quick-N-Big) for 2 years under combinations of nitrogen rates and harvesting management. The experimental design was in randomized complete blocks with five treatments and three replications for each crabgrass variety, totalling 15 experimental units for Mojo and 15 for Quick-N-Big, in adjacent fields. Treatments were combinations of nitrogen rates (0, 112, and 224 kg N/ha) and harvest management (harvesting once or twice during the growing season). Nitrogen fertilization increased FA in Mojo and Quick-N-Big. The combination of two harvests and 224 kg N/ha (H2N224) resulted in a total forage accumulation (TFA) of 7840 kg DM/ha/yr for Mojo in 2020 and 8550 kg DM/ha/yr for Quick-N-Big in 2021. The H2N224 management also resulted in the highest crude protein (CP) accumulation. Nitrogen fertilization accelerates plant maturity, which can increase neutral detergent fibre (NDF). In this case, harvesting twice stimulates new tissue production, limits NDF and increases CP and total digestible nutrients (TDN). Therefore, increasing harvesting frequency (twice during the growing season) as N is input increases TFA, CP and TDN, and also enhances N recovery, which may contribute to reducing animal supplementation costs and improve the economic return of forage-based livestock systems.

Introduction

Tall fescue (*Festuca arundinacea* Schreb.) is one of the primary cool-season perennial grasses for cattle in the US. However, it becomes dormant in the summer (Ding and Missaoui, 2016) negatively impacting forage availability during the summer months. Alternatives such as the implementation of crabgrass (*Digitaria* spp.) have been proposed to increase the forage supply. Crabgrass is an annual warm-season forage with a high-quality forage that vigorously grows during the summer (Moyer and Sweeney, 2011), and also has a high capacity for self-reseeding (Teutsch *et al*., 2005).

Among the varieties, 'Mojo' [*Digitaria ciliaris* (Retz.) Koeler] is a blend of the 'Red River' and 'Impact'. Impact has a later maturity when compared to Red River. 'Quick-N-Big' (*Digitaria aegyptiaca* Willd.) is recognized for its fast germination and high growth rate, reaching an adequate grazing or hay stage about 2 weeks earlier and with higher forage accumulation (FA) than Red River (Dalrymple, 2010).

Crabgrass grows in a variety of soil types but is best suited to well-drained sandy loam and sandy clay loam soils (Blount *et al*., 2003). Crabgrass is also highly responsive to nitrogen (N) fertilization (Teutsch *et al*., 2005; Sosinski *et al*., 2022), which is the most limiting nutrient in agricultural systems (Blumenthal *et al*., 2008). The lack of N is especially important in hayfields, where nutrient removal tends to be greater than in grazing systems (Dubeux and Sollenberger, 2020). Nitrogen is a fundamental component of several cell compounds (amino acids, proteins and nucleic acids) (Taiz *et al*., 2015), and its use as fertilizer stimulates cell elongation rate (Fricke *et al*., 1997) and cell division (MacAdam *et al*., 1989), increasing tillering, root mass and FA (Faria *et al*., 2018). Additionally, it can improve forage crude protein (CP; Teutsch *et al*., 2005) and total digestible nutrients (TDN; Kering *et al*., 2011).

Harvesting frequency is another important management practice to stimulate growth and tissue turnover in forage systems. Shortening the regrowth period increases leaf proportion and reduces dead material and stem proportions (Silva *et al*., 2015), consequently, decreasing fibre and lignin contents (Hodgson, 1990). Furthermore, young leaves have higher photosynthetic potential compared to mature ones (Parsons *et al*., 1983; Yasuoka *et al*., 2018). For these reasons, pastures more frequently harvested may increase FA and improve nutritive value.

Previous studies have evaluated the crabgrass responses to N rates using different N sources (Teutsch *et al.*, 2005; Sosinski *et al.*, 2022) or sources associated with application timing (Moyer and Sweeney, 2011; Moyer *et al.*, 2012). However, research on the impact of N fertilization associated with harvesting management is still scarce for crabgrass.

Even knowing that harvest frequency has a great impact on FA and nutritive value especially when N is applied, crabgrass hayfields are still being harvested just once, towards the end of the growing season. Based on that, we hypothesized that the increased harvest frequency associated with high N rates increases the FA and nutritive value in crabgrass varieties. Our objective was to evaluate TFA and nutritive value of two crabgrass varieties (Mojo and Quick-N-Big) under N fertilization and harvesting frequency.

Materials and methods

Site description

The research was carried out at the Southeast Research and Extension Center in Columbus, KS (37°21'N, −94°86'W, 278 m a.s.l.). The climate is classified as a humid subtropical climate according to Köppen, characterized by hot and humid summers, and mild to cool winters (Peel *et al.*, 2007). The weather (rainfall and average temperature; Fig. 1) during the growing season was recorded at the Mesonet station in Cherokee (Patrignani *et al.*, 2020), located 9.7 km from the experimental area. The predominant soil type was Parsons silt loam (fine, mixed, active, thermic Mollic Albaqualfs) with 20 ppm of P, 96 ppm of K and pH in H_2O of 5.2 (0–15 cm soil samples taken in May 2020).

The pastures were established on 21 May 2020. The field was disked, and field cultivated before seeding with a Brillion seeder, dropping seeds in front of packing wheels to a scant 1 cm depth at a rate of 6.7 kg/ha. After planting, a cultipacker was used to provide a firm seedbed. It rained shortly after sowing and continued raining for several days. A total of 101 mm of rain was reported from 22 to 30 May 2020, making soils very wet. However, after 31 May 2020, there was only 41 mm of rain for the next 61 days, causing soil moisture to be depleted. Because of the dry weather, grass growth was slowed and harvest was delayed until 20 August 2020. Growing conditions were favourable after the mid-season harvest, which allowed for a second harvest on 9 October 2020. In 2021, the treatments were applied to the same plots without the need for reseeding and the rainfall was more consistent throughout the summer.

Experimental design and treatments

The experimental period was from 19 June to 9 October 2020 and 24 May to 12 August 2021. The experimental design was a randomized complete block with five treatments and three replications for each crabgrass variety, totalling 15 experimental units for Mojo and 15 for Quick-N-Big, in adjacent fields. Each plot was 18 m long by 3 m wide. The treatments were five combinations of three nitrogen rates (0, 112 and 224 kg/ha, labelled N0, N112 and N224, respectively) and two harvest management in an incomplete factorial. Harvest management was defined as harvested once (H1; late in the season) or harvested twice (H2; mid- and late-season). Thus, the treatments were: H1N0, harvested once without N fertilization; H2N0, harvested twice without N fertilization; H1N112, harvested once with 112 kg N/ha at the beginning of the growing season; H2N112, harvested twice with 112 kg N/ha at the beginning of the growing season; and H2N224, harvested twice with 112 kg N/ha at the beginning of the growing season + 112 kg N/ha after the mid-harvesting harvest (Table 1). Management with one harvest and two N fertilization was not included because it is not a recommended practice (Ball *et al.*, 2015). The mid-season harvest occurred on 20 August 2020 and 7 July 2021 for twice-harvested plots (H2N0, H2N112 and H2N224), and late-season harvesting occurred on 9 October 2020 and 12 August 2021 for all treatments. Because the pastures were established in May 2020, the mid- and late-season harvests occurred later in 2020 compared to 2021, when the pastures were already well established.

In 2020, H1N112 and H2N112 treatments were fertilized with 112 kg N/ha on 19 June 2020, and in the H2N224 an additional N fertilization (112 kg N/ha) was done on 21 August 2020. The

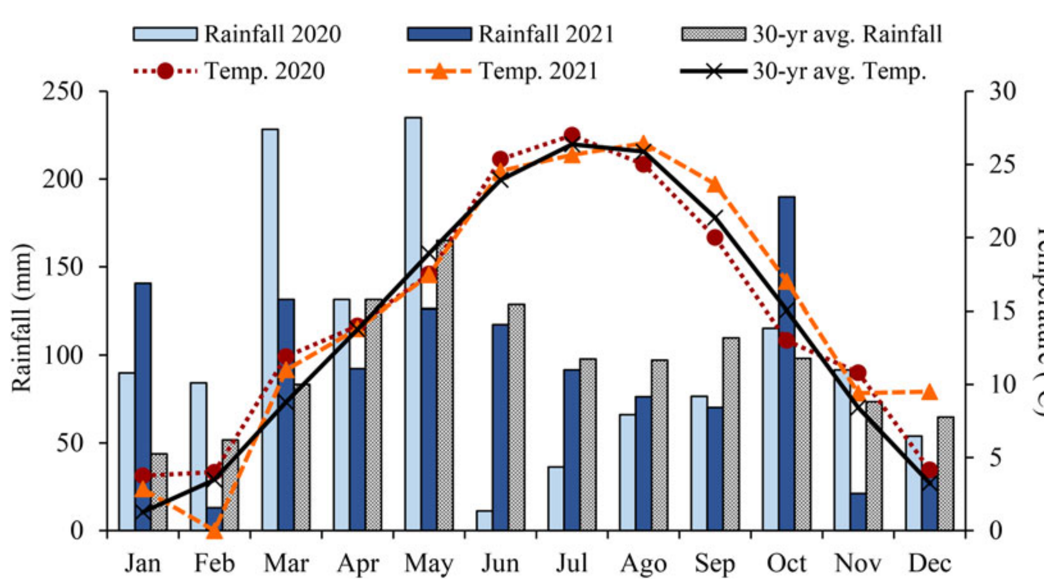

Figure 1. Monthly total rainfall and mean temperature during the experimental period and the previous 30-year (1991–2021) average.

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Table 1. Management as a combination between N rates (0, 112 or 224 kg/ha/yr) and harvest frequency (one or two harvests per year)

Management	N rate (kg N/ha/yr)	Harvest
H1N0	0	Late-season
H2N0	0	Mid- and late-season
H1N112	112	Late-season
H2N112	112	Mid- and late-season
H2N224	224	Mid- and late-season

The mid-season harvest occurred on 20 August 2020 and 7 July 2021, and late-season harvest occurred on 9 October 2020 and 12 August 2021.

procedure was repeated in 2021, when the treatments with 112 kg N/ha were fertilized on May 24, and the second N fertilization was applied in the H2N224 on July 9. Nitrogen was manually spread as urea according to the treatments.

Total forage accumulation, nutritive value and nitrogen recovery

In each growing season, FA was quantified at harvesting dates by sampling a 0.9 by 4.6 m area in each plot using a flail harvester (Carter®) to 6 cm stubble height. The FA samples were dried at 55°C in a forced air dryer until constant weight and weighed. Total forage accumulation (TFA) was calculated by summing the FA in each year.

The dried samples were ground in a Wiley mill to 1 mm and analysed for CP (AOAC, 2016; Method 976.06), NDF (Ankom Technology, 2006b; Method 6), ADF (Ankom Technology, 2006a; Method 5) and concentrations of Ca (AOAC, 2016; Method 956.01) and P (AOAC, 2016; Method 965.17). Crude protein accumulation (CPA) was calculated by multiplying the FA by the CP content at each harvest, and TDN was estimated according to NRC (1989).

To calculate the nitrogen recovery, the CPA was divided by 6.25 to estimate the amount of N extracted by the plants. For H1N112, the obtained value was subtracted from H1N0 (control) and divided by the N rate (112 kg N/ha). For H2N112 and H2N224, the same procedure was done but using H2N0 as the control and dividing by 224 kg N/ha. Results are presented in percentages. Nitrogen recovery was not calculated for H1N0 and H2N0.

Statistical analysis

The data were analysed using a mixed-model method with a parametric structure in the covariance matrix through the MIXED procedure of SAS 9.4 (Littell *et al*., 2006) with repeated measurements and using the maximum likelihood restricted method. Block and harvest were considered as random effects, whereas management, year and management × year interaction were fixed effects. Each variety was analysed separately. The nutritive value variables from treatments harvested twice are presented as a single average as harvest was considered as random 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 ($P < 0.05$).

Results

Total forage accumulation

The TFA was affected by management and year for Mojo (Table 2) and by management × year interaction for Quick-N-Big (Table 3). For both varieties, TFA was greater when N was applied (H1N112, H2N112 and H2N224) than in the non-fertilized treatments (H1N0 and H2N0) (Tables 4 and 5). The TFA was higher in 2020 compared to 2021 for Mojo (Table 6).

Forage nutritive value

For Mojo, CP, ADF, TDN and concentrations of Ca and P were affected by management × year interaction (Table 2). Neutral detergent fibre (NDF) was affected by management and by year (Table 2). Overall, CP was higher in treatments harvested twice than those harvested once (H2N0 *vs.* H1N0 and H2N112 *vs.* H1N112), and for both years, the highest values were registered when harvested twice with the highest N rate (H2N224; Table 7). Acid detergent fibre was higher in the treatments harvested once (H1N0 and H1N112) in 2020 and in H2N112 in 2021. NDF was higher in the H1N0 (Table 4) and in 2021 (Table 6). TDN were similar among the managements in 2020 and were higher in the treatments harvested once (H1N0 and H1N112) in 2021. The highest values for Ca concentration in 2020 and 2021 were registered in the H1N112 and H2N0, respectively. The lowest P concentration values were registered in H1N112 in both years (Table 7).

Table 2. *P*-values for 'Mojo' crabgrass as affected by management (combination of N fertilization and harvesting frequency), year and management × year interaction during 2 years in Columbus, KS

	Effect		
Variable	Management	Year	Management × year
Total forage accumulation	<0.001*	0.040*	0.317
Crude protein	<0.001	0.052	0.019*
Crude protein accumulation	<0.001*	0.061	0.466
Acid detergent fibre	0.022	0.017	0.026*
Neutral detergent fibre	0.022*	0.006*	0.100
Total digestible nutrients	0.492	0.004	0.020*
Ca concentration	0.003	0.879	0.044*
P concentration	<0.001	<0.001	0.006*
Nitrogen recovery	0.014*	0.927	0.977

*Significant at 0.05 level. Interaction (treatment × year) supersedes main effects when significant.

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Table 3. *P*-values for 'Quick-N-Big' crabgrass as affected by management (combination of N fertilization and harvesting frequency), year and management × year interaction during 2 years in Columbus, KS

	Effect		
Variable	Management	Year	Management × year
Total forage accumulation	<0.001	<0.001	<0.001*
Crude protein	<0.001	0.223	<0.001*
Crude protein accumulation	<0.001	0.004	0.002*
Acid detergent fibre	0.079	<0.001	<0.001*
Neutral detergent fibre	0.001	0.003	<0.001*
Total digestible nutrients	0.040	<0.001	<0.001*
Ca concentration	0.045	<0.001	<0.001*
P concentration	<0.001	<0.001	<0.001*
Nitrogen recovery	0.773	<0.001*	0.127

*Significant at 0.05 level. Interaction (treatment × year) supersedes main effects when significant.

For the Quick-N-Big, management × year interaction affected CP, ADF, NDF, TDN, Ca and P concentrations (Table 3). Treatments harvested twice and fertilized (H2N112 and H2N224) had higher values of TDN in 2020 and CP for both years, and the opposite pattern was registered for ADF and NDF in 2020 (Table 5). The highest Ca concentration was found in H1N112 in 2020 and H2N0 and H2N224 treatments in 2021. The once-harvested treatments had lower P concentrations in 2020, and in 2021, higher values in treatments without N (H1N0 and H2N0) compared to treatments with N fertilization (Table 5).

Crude protein accumulation

The CPA was affected only by management for Mojo (Table 2) and by management × year interaction for Quick-N-Big (Table 3). Regardless of the varieties or year, CPA was lower in the treatments without N fertilization (H1N0 and H2N00) (Tables 4 and 5). Overall, on fertilized pastures, twice harvests resulted in the highest CPA (H1N112 *vs.* H2N112). For both varieties, the treatment that associated two harvests with the highest N rate (H2N224) registered the greatest CPA.

Nitrogen recovery

Nitrogen recovery was affected by management for Mojo (Table 2) and by year for Quick-N-Big (Table 3). Mojo nitrogen recovery was higher in H2N112 and H2N224 than in H1N112 (Table 4), and Quick-N-Big nitrogen recovery was lower in 2020 than in 2021 (18.5 and 44.4%, respectively).

Discussion

Nitrogen fertilization increased crabgrass TFA showing the potential to improve agronomic performance in crabgrass hayfields. When N rates are compared under the same harvest management (once or twice per year), the TFA was increased in the treatments with N fertilization (Tables 4 and 5). In the treatments with one harvest per year (H1N0 and H1N112), fertilization with 112 kg N/ha increased TFA for both varieties. When harvested twice, the N effect was more intense when 112 kg N/ha were applied, with a TFA increase only for Quick-N-Big in 2021 at the rate of 224 kg N/ha. These effects in FA can be attributed to the capacity of N to increase the rates of enzymatic reactions, plant metabolism and the morphogenic and structural characteristics of the canopy (Volenec and Nelson, 1984). The positive N impact on crabgrass FA was also observed by Teutsch *et al.* (2005) and Sosinski *et al.* (2022) showing crabgrass responsiveness to N fertilization.

Given the lack of effect between N0 treatments (Table 4 and 5), harvesting once a year might be an alternative to reduce production costs without compromising TFA. The absence of N fertilization, however, reduced TFA in 2021 for Quick-N-Big, which may be related to the seedbed preparation during the first experimental year for pasture establishment. Soil tillage and disturbance have been shown to stimulate soil microbial activity, resulting in the mineralization of soil organic matter (Lienhard *et al.*, 2014), and improving nutrient availability (Craswell and Lefroy, 2001). This may account for the observation that 2020 TFA was greater than 2021 for Mojo and for Quick-N-Big when N was not applied.

Higher TFA in 2021 in the N-fertilized treatments in Quick-N-Big may be also due to some N carryover from 2020

Table 4. Total forage accumulation, crude protein accumulation, neutral detergent fibre and nitrogen recovery in Mojo as affected by N fertilization and harvesting frequency during 2 years in Columbus, KS

Management	Total forage accumulation kg DM/ha/yr	Crude protein accumulation kg CP/ha/yr	Neutral detergent fibre %	Nitrogen recovery % N extracted
H1N0	3000 C	138 B	66.4 A	–
H2N0	2700 C	234 B	61.7 C	–
H1N112	4650 B	234 B	63.6 BC	14.2 B
H2N112	6190 A	484 A	63.5 B	36.6 A
H2N224	6090 A	659 A	61.7 C	36.0 A
SEM	503	55.6	1.2	4.14

Management were five combinations of two harvest frequencies [once (H1) or twice (H2) per year] and nitrogen rates (0, 112 and 224 kg/ha, labelled as N0, N112 and N224, respectively); uppercase letters compare means between managements ($P < 0.05$); S.E.M., standard error of the mean.

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Table 5. Total forage accumulation, crude protein, crude protein accumulation, acid detergent fibre, neutral detergent fibre, total digestible nutrients and concentrations of Ca and P in Quick-N-Big as affected by N fertilization and harvesting frequency during 2 years in Columbus, KS

	Management					
Year	H1N0	H2N0	H1N112	H2N112	H2N224	S.E.M.
	Total forage accumulation (kg DM/ha)					
1	2780 b	2370 b	3515 a	3540 a	3405 a	152
2	1745 c	1405 c	7540 a	4660 b	7635 a	551
P value	0.068	0.085	<0.001	0.050	<0.001	
	Crude protein (%)					
1	4.4 c	7.1 b	7.2 b	9.5 a	9.1 a	0.29
2	4.8 d	8.4 c	4.7 d	9.5 b	11.0 a	0.23
P value	0.327	0.001	<0.001	0.948	<0.001	
	Crude protein accumulation (kg CP/ha/yr)					
1	122 c	160 c	252 b	343 a	337 a	15.2
2	87 c	107 c	355 b	412 b	817 a	68.2
P value	0.628	0.465	0.168	0.340	<0.001	
	Acid detergent fibre (%)					
1	46.8 a	42.1 b	45.2 a	38.8 c	39.0 c	1.86
2	35.6 a	36.8 a	36.1 a	38.1 a	38.3 a	1.85
P value	<0.001	<0.001	<0.001	0.604	0.621	
	Neutral detergent fibre (%)					
1	67.5 a	62.8 b	65.8 a	59.6 c	59.7 c	1.06
2	64.8 ab	62.4 b	65.4 a	66.1 a	64.7 a	1.11
P value	0.045	0.700	0.693	<0.001	<0.001	
	Total digestible nutrients (%)					
1	38.9 c	45.8 b	40.8 c	50.4 a	49.6 a	3.13
2	56.0 a	54.0 a	55.3 a	52.4 a	52.0 a	3.13
P value	<0.001	<0.001	<0.001	0.343	0.262	
	Ca concentration (%)					
1	0.50 ab	0.47 b	0.57 a	0.52 ab	0.52 ab	0.021
2	0.40 b	0.49 a	0.40 b	0.43 b	0.50 a	0.014
P value	0.003	0.28	<0.001	<0.001	0.455	
	P concentration (%)					
1	0.10 c	0.21 a	0.08 c	0.19 ab	0.15 b	0.017
2	0.37 a	0.34 a	0.20 b	0.22 b	0.20 b	0.020
P value	<0.001	<0.001	<0.001	0.161	0.036	

Management was five combinations of two harvest frequencies [once (H1) or twice (H2) per year] and nitrogen rates (0, 112 and 224 kg/ha, labelled as N0, N112 and N224, respectively) (Table 1); lowercase letters compare means between managements ($P < 0.05$); S.E.M., standard error of the mean; *P* value compare years.

to 2021. Sweeney and Diaz (2014), evaluating N carryover effects in a silt loam claypan soil in the same region, reported an increase in wheat grain production and residual soil NO_3–N. The residual increment was as high as the N rate in the past year. Therefore, for treatments H1N112, H2N112 and H2N224 in Quick-N-Big, part of N applied in 2020 may have been carried over to 2021 which resulted in higher TFA in 2021. The combination of harvest management with N fertilization for both crabgrass varieties can be different when the objective is to increase the FA. For Mojo, the application of 112 kg N/ha combined with two harvests per year resulted in greater TFA. However, Quick-N-Big had lower TFA in H2N112 when compared to H1N112 in 2021, and similar TFA was measured in 2020, demonstrating no benefits for the additional harvest if only 112 kg N/ha was applied (Table 5).

Higher CP values were expected in the treatments with N fertilization (Tables 5 and 7), as has been reported in other studies (Johnson *et al.*, 2001; Teutsch *et al.*, 2005; Kering *et al.*, 2011). However, N fertilization accelerates the physiological process

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Table 6. Total forage accumulation and neutral detergent fibre in Mojo during 2 years in Columbus, KS

	Variable	
	Total forage accumulation	Neutral detergent fibre
Year	kg DM/ha/yr	%
1	4990	62.0
2	4060	64.8
P value	0.040	0.006
S.E.M.	386	1.17

P value compares years; S.E.M., standard error of the mean.

leading plants to reach maturity even earlier during the growing season. For this reason, treatments fertilized with 112 kg N/ha but harvested once (H1N112) presented, overall, lower CP content than twice-harvested treatments (H2N0, H2N112 and H2N224; Tables 5 and 7). Beck *et al.* (2007) also reported a linear decrease in CP in crabgrass from 15.6 to 11.0% when the harvest interval increased from 21 to 49 days due to the increase in plant maturity.

Treatments without N fertilization (H1N0 and H2N0) and H1N112 also presented CP content below 7%, which is considered the minimum value to keep a healthy rumen (NRC, 2001). To grow a 450–600 lb steer or heifer, gaining 1.5 lb/day, CP requirements will be from 9.5 to 8.6% (NRC, 2001). Thus, N fertilizer combined with more frequent harvest (i.e. twice a year) is also an alternative to match the nutrient requirement of some animals' categories.

The positive N effect on both TFA and CP resulted in higher CPA in the treatments with N (Tables 4 and 5). Overall, higher CPA also occurred when fertilized pastures were harvested twice mainly due to the increase in CP (Tables 5 and 7). The greater the CPA the lower the total protein supplementation needs in a livestock operation, which will positively impact supplementation costs.

Nitrogen fertilization stimulates plant growth, which also increases the proportions of carbon allocated to the canopy structure (Irving, 2015), enhancing stem proportion and fibre deposition (Tesk *et al.*, 2018). In the late stages of regrowth, the leaf death rate has also increased (Hodgson, 1990; Lemaire and Chapman, 1996). Thus, the forage produced may have had a higher stem and dead material proportions. This may explain the higher values of ADF for Mojo (Table 7) and NDF for Quick-N-Big (Table 5) in 2021 in the N-fertilized treatments (H1N112, H2N112 and H2N224). These results demonstrate that nitrogen fertilization in crabgrass can be an important tool to increase TFA but needs to be associated with harvest management to not increase ADF and NDF values.

Table 7. Crude protein, acid detergent fibre, total digestible nutrients and concentrations of Ca and P in Mojo as affected by N fertilization and harvesting frequency during 2 years in Columbus, KS

	Management					
Year	H1N0	H2N0	H1N112	H2N112	H2N224	S.E.M.
	Crude protein (%)					
1	4.2 c	6.8 bc	6.7 c	9.9 b	12.5 a	0.91
2	5.1 cd	7.6 b	4.5 d	7.1 bc	10.1 a	0.68
P value	0.673	0.017	0.263	<0.001	<0.001	
	Acid detergent neutral (%)					
1	42.7 a	36.2 bc	42.0 a	36.0 c	39.0 ab	1.07
2	34.7 b	37.3 ab	35.4 ab	38.3 a	37.5 ab	0.78
P value	0.031	0.343	0.056	0.092	0.235	
	Total digestible nutrients (%)					
1	46.2 a	50.9 a	47.1 a	51.8 a	50.1 a	1.43
2	58.0 a	52.2 b	57.1 a	49.8 c	51.4 b	0.92
P value	0.016	0.334	0.030	0.108	0.273	
	Ca concentration (%)					
1	0.29 c	0.39 ab	0.46 a	0.35 bc	0.41 ab	0.051
2	0.32 c	0.47 a	0.36 bc	0.35 c	0.41 b	0.052
P value	0.415	0.020	0.032	0.952	0.903	
	P concentration (%)					
1	0.17 b	0.23 a	0.07 c	0.20 ab	0.20 ab	0.036
2	0.37 a	0.35 a	0.17 c	0.25 b	0.25 b	0.036
P value	<0.001	<0.001	0.005	0.074	0.042	

Management was five combinations of two harvest frequencies [once (H1) or twice (H2) per year] and nitrogen rates (0, 112 and 224 kg/ha, labelled as N0, N112 and N224, respectively) (Table 1); lowercase letters compare means between managements ($P < 0.05$); S.E.M., standard error of the mean; *P* value compare years.

Maturity may also have been contributing to higher ADF and NDF in H1N0 and H1N112. During the regrowth, cell wall proportion increases (Bidlack and Buxton, 1992) and, therefore, harvest stimulates new tissue production which has higher nutritive value. Thus, treatments harvested twice may have had less cell wall content resulting in lower ADF and NDF.

The TDN values from 38.9 to 58.0% in the present study were lower than those reported by Sosinski *et al.* (2022). These authors measured TDN ranging from 59.6 to 65.0% when crabgrass was fertilized with mineral fertilizer (up to 480 kg of N/ha) or with broiler poultry litter (up to 472 kg of N/ha). Beck *et al.* (2007) reported that TDN decreased linearly in crabgrass as the harvest intervals increased. The same pattern was not highlighted in the present study because the TDN within the same N fertilization rate was higher in the twice-harvested treatments only for Quick-N-Big in 2020. The TDN values observed in our study were not able to match the requirements of growing steers or heifers, indicating the need for energy supplementation.

Calcium concentrations did not show a clear pattern in response to N fertilization and harvest management. This demonstrates that other uncontrolled factors in the present study affected these responses. The Ca concentration ranged from 0.29 to 0.50% in treatments without N, 0.35 to 0.57% at the 112 kg N/ha rate and 0.41 to 0.52% when 224 kg/ha of N was applied (Tables 5 and 7). These values are similar to those reported by Kering *et al.* (2011) studying another warm-season grass [Bermudagrass (*Cynodon dactylon* (L.) Pers.)] fertilized with 0, 112 and 224 kg N/ha (0.39, 0.40 and 0.44%).

The P concentration values tended to be lower when nitrogen was applied (Tables 5 and 7) potentially due to the competitive inhibition of absorption among cations or due to the dilution effect as FA increases. This may arise from reduced nutrient concentrations in the forage, such as P and K (Tesk *et al.*, 2018). Therefore, although nitrogen significantly increases the FA, a reduction in the nutrient concentration, such as phosphorus, may be observed.

Higher N recovery usually occurs in high-rainfall conditions because plants can grow faster requiring higher N input (McCaughey and Simons, 1998). Similien *et al.* (2015) postulated that nutrient uptake is higher when conditions for plant growth are favourable. Therefore, higher precipitation in 2021 may have provided a better environment for plants to improve their capacity to recover the applied N in Quick-N-Big pastures.

Higher N recovery in treatments harvested twice (H2N112 and H2N224) in Mojo shows that harvest management can also impact the plant's capacity to uptake N. It occurred because H2N112 and H2N224 had greater TFA and CP than H1N112 (Tables 4 and 7). According to McCartney *et al.* (2004), forage plants remove more N in multiple harvesting systems because plants are predominantly in the vegetative stage and, therefore, have high N concentrations. According to Similien *et al.* (2015), N removal for multiple harvests exceeded the single harvest from 29 to 234%.

Conditions that favoured forage production during late summer and early autumn resulted in the highest nutrient uptakes. These issues and the possibility that, when frequently clipped or grazed, grasses may take up more applied N than when harvested for hay further indicate the need for additional study on fertilizer application for grass pastures. Nitrogen uptake (and therefore recovery) was greater when harvested twice, since it was mainly in the vegetative stages, while the once-harvested forage was more mature (McCartney *et al.*, 2004).

Conclusion

The fast growth promoted by the N fertilization increases TFA but also accelerates plant maturity negatively impacting nutritive value (increases ADF and NDF concentrations). Thus, intensifying harvest frequency (harvesting twice during the growing season) when N is applied in crabgrass pastures is essential to increase TFA, CP and CPA, and, at the same time, improve the N recovery. All these benefits together contribute to enhancing forage production efficiency and reducing animal supplementation costs.

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