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Effect of fertilization, intensity, frequency and season of defoliation on herbage yield and nutritive value of *Cenchrus ciliaris* L.

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Abstract
Common buffelgrass (*Cenchrus ciliaris* L.) was studied in a field experiment under two fertility levels (0 or 50 kg N ha^{-1}), two cutting heights (5 or 15 cm above ground level), two cutting frequencies (21 or 42 days), during a 126 day growing season. Results showed significant highest yields with the least frequent, more severe defoliation. The highest fertility environment was favourable for yield productivity, ash and crude protein content. The effect of the intensity and frequency of defoliation suggests the need to impose appropriate defoliation stress to obtain high yield with better quality.

Key words: Buffelgrass, Clipping height, Defoliation, Fertilization, Forage production, Range grass, Shoot growth

Abbreviations: CA: crude ash, **CP**: crude protein, **D**: day, **H**: hours, **LDM**: leaf dry matter, **NOST**: number of stems, **RDM**: root dry matter, **RGM**: root green matter, **SDM**: shoot dry matter, **StDM**: stem dry matter, **StDM**: **LDM**: dry stem-dry leaf ratio

Introduction

Buffelgrass (*Cenchrus ciliaris* L.) is a C_4 erect, tufted perennial grass, native to Africa, India, and Indonesia that was introduced to Australia and America in the early 20th century. This grass is used extensively in South Texas, northern Mexico, and throughout other warm semi-arid regions of the world to improve rangelands for cattle production due to its high productivity, digestibility and palatability (Khan *et al.,* 2004). Buffelgrass has proven its ability to thrive and yield well under climatologically adverse conditions; it is especially tolerant to the seasonal droughts commonly present in northwestern and northeastern Mexico. Although these desirable characteristics are present, buffelgrass is frequently subject to overgrazing, resulting in decreased recovery and productivity (Hodgkinson *et al.,* 1989). Moreover, many climatological, edaphological and morphophysiological factors, as well as management practices have marked influence in the recovery and yield of buffelgrass (Martin-Rivera *et al.,* 1995). Despite the fact that cattle (*Bos* spp.) growers have gained abundant practical experience in buffelgrass management since it was introduced to Mexico in 1954, and some research has been completed on individual aspects of fertility and harvest management, there is little scientific research on the combined effects of these factors on this grass species. Therefore, the objective of this study was to investigate the influence of different pasture management practices such as fertilization, season of defoliations, and clipping frequency and height on yield and nutritive value of this grass.

Materials and Methods

A field experiment was conducted from July to November 2007 at the experimental farm of the School of Agronomy (Universidad Autónoma de Nuevo León) located in Marín, NL (northeastern Mexico, 364 m above sea level, 25°23´N, 100°03´W). The climate in the area is semiarid with an average annual rainfall of 466 mm. Monthly mean temperature of the coldest (January) and the hottest (July) months in the area are 16.6 and 28.4°C, respectively. Relative humidity averages 75% throughout the year.

Seeds of buffelgrass were germinated on plastic trays filled with soil and irrigated regularly with tap water after 6-month of storage to break seed dormancy. After two months, buffelgrass seedlings strictly selected for homogeneity (H”20 cm height), were transplanted to plastic bags with 4 drainage holes and containing 20 kg of collected agricultural soil: *p*H 8.1, conductivity 0.4 mS/cm, organic matter 2.1%, total nitrogen 0.1%, available phosphorus 3.8 mg/kg, available potassium 336 kg/ha and clay texture. Before transplanting, soil in the experimental bags was brought to field capacity (FC). After a two-week post-transplanting acclimation period to the experimental conditions, treatments were initiated.

We used a randomized block 2^3 factorial design with two levels of each of three factors: fertilization (0 and 50 kg N/ha), intensity of defoliation (5 and 15 cm) and cutting frequency (21 and 42 d.), for a total of eight treatment combinations. Each treatment combination was replicated 15-fold.

At the start of the experiment, and at 42 days intervals, nitrogen as $(NH_4)_2SO_4$ (20.5% N) was applied at two rates (0 and 50 kg N/ha). Plants were submitted to either of two defoliation stresses: cut at 5 or 15 cm above the ground level to simulate moderate and heavy grazing, respectively; and cutting frequencies of every 21 or 42 days. Experimental treatments were maintained for a total length of 18 weeks covering three growth periods (A: 2 July to 13 August; B: 14 August to 24 September; and C: 25 September to 5 November) On each defoliation event, all plant shoots were harvested using garden scissors. During the growing season (summer and autumn), plants were regularly and uniformly irrigated to maintain soil moisture conditions close to 80% FC to ensure non limiting water availability.

On each defoliation event, shoot green matter (SGM) and shoot dry matter (SDM, 64ÚC, 72 h) yield was determined. Dried shoot samples were then sorted into leaf (LDM), stem (StDM) and dead material to calculate the number of stems (NoSt), the stem-leaf ratio (StDM:LDM) and for chemical analysis. Root green (RGM) and dry (RDM) matter yield was recorded only at the last harvest (126 days after sowing) for 6 replicates. Nitrogen concentration (Kjeldahl method) and crude ash (CA) concentration (550°C, 48 h) of the herbage (only shoots) were determined. The crude protein content (CP) was estimated as N% × 6.25. For all analyses, blanks and known standard samples were analyzed to ensure consistency.

Statistical analyses for plant variables included ANOVA, interaction and correlation (Assistat ver 7.6 beta, 2011). Comparisons of mean values were based on their LSD. For statistical purposes, data for every two short defoliation frequencies (21 d) within each long defoliation frequency (42 d) were combined, as a result, the ANOVA reports only three harvests. Root parameters were analyzed only after the final harvest and included 6 replications.

Results and Discussion

Growth and yield: There were significant differences (p**£**0.01) in dry matter production due to N levels, cutting, harvest frequency, and periods of defoliation for all characters studied (Table 1). The highest yields (expressed as total shoot dry matter production) resulted from the least frequent (42 d), more severe defoliation (5 cm).

In the present study, the high fertility (50 kg N/ha) environment was favourable ($p \leq 0.01$) for all characters studied, this in accordance with numerous previous reports (Khan *et al.,* 2004). All plant parameters were affected ($p \leq 0.01$) by the intensity of defoliation (Table 1). Positive effects ($p \leq 0.01$) were found for SDM, StDM and StDM:LDM at the most severe defoliation treatment (5 cm), whereas the opposite effect was found for NoSt and LDM.

All plant parameters evaluated were affected ($p \leq 0.01$) by frequency of defoliation (Table 1). Defoliation is known to differentially affect various grass growth parameters (Ferraro and Oesterheld, 2002). For instance, LDM, NoSt and StDM:LDM were significantly greater for the most frequent defoliation (21 d), while a larger recovery time (42 d) was needed for SDM and StDM. Similar results are reported recently by Sardar (1993) who found that buffelgrass is sensitive to continuous cuttings; however our results were also dependent on the fertilization rate, season and intensity of defoliation. Overall, cutting interval had greater impact on plant growth than cutting height (Table 1).

All plant parameters were significantly affected ($p \leq 0.01$) by the season of defoliation (Table 1). The highest yields (SDM, LDM, StDM and StDM:LDM) were obtained in the first summer cutting (42 d) and productivity was reduced by the third cycle (126 d), corresponding to the autumn cutting. This effect is thought to be caused by the experimental treatments and seasonal changes in environmental conditions (light, temperature, precipitation).These findings support other studies which have reported significant interactions among experimental treatments (*i.e.* clipping height and intensity, N fertilization) and a marked defoliation seasonal effect on grass yield (Caraballo and González, 1991; Sardar, 1993). Furthermore, environmental factors, such as soil, climate, nutrients, light, soil moisture and season of cutting could also modify and interact with the effects of defoliation (Martin-Rivera *et al.,* 1995; Ferraro and Oesterheld, 2002); thus, these too need to be taken into account.

Tillering (*i.e.* NoSt) was negatively influenced ($p \leq 0.01$) by intensity of defoliation (Table 1). Some earlier reports have associated this effect with photosynthates allocation and apical dominance (Issoufou *et al.*, 2008). Cutting height of 15 cm increased tillering, but reduced overall plant growth (Table 1). On the other hand, our research showed that frequent defoliation stimulated tillering; this observation is consistent with studies using buffelgrass in Texas, USA (Harrison, 1934) irrespective of the level of N fertilization and in Australia without N fertilization (Hodgkinson *et al.*, 1989). In the present study, however, tiller density was higher in treatments with N fertilization as compared to the control treatment (Table 1).

Table 1. Effect of fertilization, intensity, frequency and season of defoliation on selected yield parameters of common buffelgrass (*Cenchrus ciliaris* L.) (Data of three harvests, mean values are presented, n=45 to 90).

		Herbage parameters				
		SDM (g)	**LDM (g)**	**StDM (g)**	**NoSt**	**StDM:LDM**
Fertilization kg N ha^{-1}	**0**	24.7[a]	14.8[a]	11.9[a]	55.3[a]	0.75[a]
	50	30.0[b]	15.6[b]	16.7[b]	66.1[b]	1.04[b]
Cutting height (cm)	**5**	28.2[a]	14.9[a]	15.4[a]	54.3[a]	0.96[a]
	15	26.6[b]	15.6[b]	13.2[b]	67.1[b]	0.83[b]
Defoliation frequency (d)	**21**	23.3[a]	15.8[a]	9.71[a]	66.8[a]	0.54[a]
	42	31.4[b]	14.6[b]	18.8[b]	54.7[b]	1.25[b]
Defoliation season	**A**	34.9[a]	18.7[a]	19.1[a]	57.0[b]	1.04[a]
	B	32.8[b]	17.3[b]	18.1[a]	70.8[a]	1.10[a]
	C	14.5[c]	9.66[c]	5.59[b]	54.3[b]	0.55[b]

Values followed by different letters represent treatment means that are significantly different at (p = 0.05). SDM: shoot dry matter; LDM: leaf dry matter; StDM: stem dry matter; NoSt: number of stems; StDM:LDM: dry stem-dry leaf ratio. Defoliation season (year 2007), A: 2 July to 13 August; B: 14 August to 24 September; and C: 25 September to 5 November.

Leaf yield (LDM) productivity declined progressively ($p \leq 0.01$) over each defoliation event. Fertilization enhanced ($p \leq 0.01$) LDM yield; a similar effect was observed with the less intense defoliation treatment by cutting at 15 cm ($p \leq 0.05$) (Table 1). In contrast, more frequent defoliation (every 21 d) increased ($p \leq 0.01$) LDM yield more than less frequent defoliation. The stem-leaf ratio (StDM:LDM) was consistently affected by all the experimental variables. Nitrogen fertilization and the less frequent defoliation treatments resulted in more ($p \leq 0.01$) LDM than StDM productivity with the reverse effect ($p \leq 0.05$) caused by the most severe defoliation treatment (5 cm). Stem to leaf ratio did not vary significantly in the summer period (first and second defoliations), but it did show a higher proportion of leaves on the last defoliation (autumn: 25 September to 5 November).

Frequency of defoliation showed to reduce root mass more than intensity (Table 2). Cutting height did not affect ($p \geq 0.05$) total RDM but affected total RGM ($p \leq 0.05$). More frequent defoliations reduced RDM ($p \leq 0.01$) and RGM ($p \leq 0.05$). Nitrogen fertilization affected negatively ($p \leq 0.05$) root production expressed as RDM and RGM as compared to the control treatments (0 kg/N).

Table 2. Effect of fertilization, intensity, frequency and season of defoliation on root biomass of common buffelgrass (*Cenchrus ciliaris* L.) (Data are the means of 6 replicates).

		Root parameters	
		RGM (g)	**RDM (g)**
Fertilization kg N ha^{-1}	**0**	66.7[a]	31.5[a]
	50	45.1[b]	25.8[b]
Cutting height (cm)	**5**	50.6[a]	28.9[a]
	15	61.2[b]	28.3[a]
Defoliation frequency (d)	**21**	51.0[a]	24.5[a]
	42	60.8[b]	32.7[b]

Values followed by different letters represent treatment means that are significantly different at (p = 0.05). RGM:root green matter; RDM: root dry matter.

These results are in agreement with other studies reporting N Fertilization-enhanced productivity but not root growth in grass forage. For example, Harrison (1934) reported that increases in N-fertilization delayed buffelgrass root growth responses after cutting, while N-fertilization and temperature enhanced both stem and leaf growth. Conversely, several studies using a number of grass species (Ferraro and Oesterheld, 2002) have shown that, in general, the severity and regularity of defoliation stress are correlated with reductions in root biomass. This is to be expected as a direct result of defoliation stress on photosynthetically active tissues.

Defoliation-enhanced reductions in root mass system are generally attributed to carbohydrate shortages that limit normal root growth as most assimilated carbon is allocated mainly to the regrowth of new shoots and leaves, which become the number one priority after defoliation stress to use available assimilation potential and reserve carbohydrates in alleviating biomass reduction by an intense and/or frequent cutting (Issoufou *et al.*, 2008). There was no significant interaction ($p \geq 0.05$) among the defoliation variables on buffelgrass root biomass. Also, it is important to note that the effects of frequency and intensity of defoliation in grass species are complementary; as a result, a decline in the severity of one of them will tend to compensate for the severity of the other, as both affect the root system. On the other hand, it has been demonstrated that greater intensities of defoliation will result in extended root growth delay and higher number of roots with inhibited growth (Ferraro and Oesterheld, 2002). Moreover, under extremely severe defoliation intensities grass could suffer from root-tip degeneration, limited rhizome growth, decrease in seed productivity and even death. For higher root-rhizome production cutting at 5 cm every 42 days was the best practice. Consequently, our results strongly argue in favour of fulfilling appropriate conditions for immediate post-defoliation root recovery, otherwise plant mortality could cause severe losses.

Yield nutritive quality: Under the experimental condition experienced here, the highest % of CP and CA in buffelgrass plants was found with the more frequent and more severe defoliation, respectively (Table 3).

In contrast, there was no significant effect ($p \geq 0.05$) of N fertilization treatment on CP and CA content in the forage. Similar results are reported during the rainy season in Venezuela by Caraballo and González (1991) in a field experiment using buffelgrass *cv.* Biloela fertilized with 150 kg N; in this case, high CP values were found at cutting (10 cm clipping height) every 21 days; additionally, the authors reported enhanced digestibility at the same interval of defoliation. The effect of intensity and frequency of defoliation on the CP and CA content (Table 3), and the significant interaction ($p \leq 0.01$) of these factors suggests the need to impose appropriate defoliation stress to obtain not only high DM yield but also better forage quality.

The correlations among biological and nutritional components were significant ($p \leq 0.01$). This validates the benefit on forage yield and quality from environmental and plant manipulation. The interaction coefficients showed different values and significance level depending on the period of defoliation and plant environment. The practical implications of these findings could be important from a pasture management point of view, since despite the fact intense and frequent defoliation practices tend to have an effect on total yield, the CP content could be increased (Table 3).The interaction variances observed in the present study revealed a significant effect of defoliation on buffelgrass performance for all characters ($p \leq 0.05$), however, caution is needed to generalize the findings of this study, as further research is needed to provide a better understanding on the effect of these treatments under different environments.

Conclusions

Nitrogen fertilization positively influenced the response capacity of buffelgrass to defoliation, and the reverse holds true for root biomass. Management under different intensities, frequencies and season of defoliation influenced growth, morphophysiological response, and nutritional quality. Optimum nutrient content obtained from this grass depends on the environmental conditions (*e.g.* fertilization, intensity, frequency and season of defoliation). The interaction variances revealed a significant effect by defoliation on buffelgrass performance for all characters, suggesting the need to impose appropriate defoliation stress to obtain high DM yield with better quality. The

Table 3. Effect of fertilization, intensity, frequency and season of defoliation on nutritive value of common buffelgrass (*Cenchrus ciliaris* L.) after 3 growth periods in one year (Data are of three defoliations, mean values are presented, n=60).

		Forage nutritional quality			
		CP (%)	**CP (g) plant^{-1}**	**CA (%)**	**CA (g) plant^{-1}**
Fertilization kg N ha^{-1}	**0**	15.0^{a}	5.12^{a}	11.5^{a}	3.94^{a}
	50	15.0^{a}	5.07^{a}	11.6^{a}	3.97^{a}
Cutting height (cm)	**5**	14.9^{a}	5.33^{a}	11.8^{a}	4.27^{a}
	15	15.1^{a}	4.85^{b}	11.3^{a}	3.63^{b}
Defoliation frequency (d)	**21**	18.0^{a}	5.65^{a}	13.9^{a}	4.37^{a}
	42	12.0^{b}	4.54^{b}	9.20^{b}	3.53^{b}

Values followed by different letters represent treatment means that are significantly different at ($p = 0.05$). CP: crude protein; CA: crude ash.

present experiment attempted to assess the importance of the combined effect of different pasture management practices (fertilization, season of defoliations, clipping frequency and height) on yield and nutritive value of this grass; however caution is needed when extrapolating results from single year experiments to extended growing periods since yield and quality parameters of perennial grasses, such as buffelgrass, may differ over time.

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