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Agronomic features of elephant grass (*Pennisetum purpureum* *S*chum) cv. Roxo under irrigation

Características agronômicas do capim elefante (*Pennisetum purpureum* *S*chum) cv. Roxo sob irrigação

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Abstract

This study aimed to evaluate how different irrigation water depths influence the agronomical features of elephant grass (*Pennisetum purpureum* *S*chum) cv. Roxo. Grass was cultivated in a pasture belonging to the Bovine Sector of the National Agrotechnical School of Caceres – MT. The experiment was a block design with five treatments and four repetitions. Treatments consisted of five water depths: 0 = 0% of available water (AW), 1 = 21% of AW, 2 = 34% of AW, 3 = 74% of AW, and 5 = 100% of AW. Evaluated features were production (dry matter ha^{-1}), plant height, leaf/steam ratio, and stem diameter. Dry matter production of cuts from May and July increased linearly with increasing water depth ($P < 0.05$). Plant height increased linearly as water depth increased in the cuts of May and September, while the height of July cuts was 71.76 cm under an irrigation depth of 390.77 mm. In May, July, and September cuts, leaf percentage decreased linearly as water depth increased ($P < 0.05$). An increase of 1 mm in water depth reduced leaf percentage by 0.0936% (May), 0.0295% (July), and 0.0122% (September). Our results indicate that to improve dry matter production, May, July, and September cuts should be irrigated with water depths of 56.03 mm, 601.78 mm, and 577.65 mm, respectively.
Key words: Forage growth. Plant height. Productivity.

Resumo

Objetivou-se com este trabalho avaliar o efeito de diferentes lâminas de irrigação em capim-elefante (*Pennisetum purpureum* Schum. cv. Roxo) sobre as características agronômicas. O capim foi cultivado em área de capineira da Escola Agrotécnica Federal de Cáceres – MT (EAFC), 16°13’42” latitude sul e 57°40’51” longitude Oeste de Greenwich. O delineamento experimental foi em blocos casualizados, com quatro repetições. Os tratamentos constaram da aplicação de cinco lâminas de irrigação, lâmina 0: 0% CC (Capacidade de campo), lâmina 1: 21% CC, lâmina 2: 34% CC, lâmina 3: 74% CC, lâmina 4: 100% CC de água disponibilizada. Foram avaliadas a produção de matéria seca (MS), altura da planta (H), porcentagem de lâmina foliar (% LF), relação lâmina foliar:colmo (F:C) e diâmetro do colmo. Nos

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cortes de maio e julho o aumento da água disponibilizada via irrigação promoveu incremento linear (P < 0,05) na produção de MS, onde cada 1 mm de água promoveu incremento de 60,11 kg MS ha^{-1} no mês de maio e 7,43 kg MS ha^{-1} no mês de julho. A (H) aumentou linearmente com o acréscimo de água disponibilizada da irrigação, atingindo a altura máxima de 56,34 cm com a lâmina d`água de 56,03 mm em maio e 63,89 cm com a lâmina d`água de 713,11 mm, enquanto no corte de julho a altura foi de 71,76 cm com a lâmina de irrigação de 390,77 mm. O aumento da quantidade de água disponibilizada promoveu redução linear (P < 0,05) da % LF no capim-elefante nos cortes de maio, julho e setembro, em que cada 1,0 mm de água de irrigação aplicada reduziu a (% LF) em 0,0936; 0,0295 e 0,0122%, respectivamente. Desta forma, do ponto de vista da produção MS ha^{-1}, sugere-se para o corte realizado no mês de maio lamina d`água de 56,03 mm, para o corte efetuado em julho lamina d`água de 601,78 mm já para o corte de realizado em setembro a lâmina d`água sugerida é de 577,65mm.

Palavras-chave: Altura. Capineira. Forragem. Produtividade.

Introduction

Seasonality in forage production is a major obstacle to the beef and dairy cattle industry because animal maintenance demands stable feed throughout the year. Seasonal fluctuations in feed supply result in the development of livestock seasons and offseasons that limit productivity.

In regions where temperature and light do not limit forage growth, irrigating pasture can reduce the effects of forage scarcity without disposing of the herd (CÓSER et al., 2008). Among the forage species most commonly grown under these conditions, elephant grass (*Pennisetum purpureum* Schum) stands out due to high yield and cattle preference.

Elephant grass is often supplemented as chopped forage in dairy production, with any rainy-season excess conserved as silage (CARVALHO et al., 1982). The plant originated in Africa and was introduced to Brazil in 1920, becoming widespread and predominantly cultivated in meadows (CARVALHO et al., 1982). Elephant grass is a high-quality, high-production forage species when cultivated under proper management, one that is based on a clear understanding of the morphological, chemical, and digestive changes that occurs throughout its vegetative cycle.

Age influences forage yield and quality; thus, plant age should not exceed 75 days when performing cutting management. During plant development, agronomic traits exhibit the most visible changes, and they are highly correlated with the nutritional and alimentary values of the forage. Of particular importance is vegetation structure, a trait that includes diameter, stem elongation, leaf and stem proportion, plant height, as well as biomass production per unit area. Increases in vegetation structure also factor into important plant characteristics such as dry matter (DM), crude protein (CP), neutral detergent fiber (NDF), and digestion rate (% h^{-1}) (GOMIDE; QUEIROZ, 1994).

The first experiments examining irrigation of forage species were developed in Piracicaba – SP (GUELFI FILHO, 1972; 1978). The results revealed that irrigating elephant grass and guinea grass increased DM yield, but did not eliminate seasonality in forage production. Furthermore, plants were three times more efficient in using water during the summer than the winter.

Elephant grass throughout Brazil has been extensively researched, particularly in the south/southeast and in the midwestern state of Mato Grosso. However, less attention has been devoted to the effects of irrigation on elephant grass pastures. Thus, this study aimed to evaluate how different irrigation levels affect the agronomic characteristics of elephant grass (*P. purpureum* cv. Roxo) in Mato Grosso.

Material and Methods

The experiment was conducted at the Federal Agrotechnical School of Caceres in southwest Mato Grosso (16°13′42″ S and 57°40′51″ W), 220 km from Cuiaba and at an altitude of 118 m. The climate is Aw (tropical savannas with wet summer and dry winter) following Köppen's classification; the dry season is from May to October and the rainy season is from November to April. Table 1 provides detailed climate data.

The elephant grass had been managed in a 2 ha area for 8 years prior to the experiment, planted with 0.8 m spacing between furrows. Over the experimental period, a standardization cut was performed (January 2007). Grass was collected in four cuts during March, May, July, and September 2007.

Soil in the area is Red-Yellow Oxisol (EMPAER, 2000), with sandy texture. Soil physicochemical properties at 0–20 cm depth were as follows: sand, 80.90 dag kg^{-1}; silt, 3.30 dag kg^{-1}; clay, 15.80 dag kg^{-1}; pH in water, 6.6; pH in $CaCl_2$, 5.8; P, 28.5 mg dm^{-3}; K, 15 mg dm^{-3}; Ca, 2.1 $cmol_c$ dm^{-3}; Mg, 1.3 $cmol_c$ dm^{-3}; Al, 0 $cmol_c$ dm^{-3}; H + Al, 1.1 $cmol_c$ dm^{-3}; organic matter, 1.44 dag kg^{-1}; sum of bases, 3.4 $cmol_c$ dm^{-3}; cation exchange capacity, 4.5 $cmol_c$ dm^{-3}; base saturation, 76%.

Based on soil analyses, the following fertilization coverage was implemented: 300 kg N ha^{-1} (ammonium sulfate) in six applications, 200 kg K_2O ha^{-1} (potassium chloride) in four applications, and 30 kg P_2O_5 ha^{-1} (ammoniated single superphosphate) plus 40 kg FTE BR 10 ha^{-1} in a single application after standardization cuts. Fertilizer recommendations and dosage were based on CFSEMG (1999). Soil moisture retention curves were determined at the UFMT Soil Physics Laboratory, using samples collected in August 2006 from undisturbed soil.

Irrigation pipes were distributed along one main line in the corridor between blocks 2 and 4, while sprinklers were set symmetrically in a bifurcation between blocks 1 and 2, equidistant from blocks 3 and 4. Pipes were installed on January 23, 2007, after plots underwent standardization cuts to a height of 10 cm above ground level. Maintenance fertilization was performed as follows: 250 kg ha^{-1} of ammonium sulfate (divided into six applications per 60 days between cuts); 83.33 kg ha^{-1} of potassium chloride (divided four applications added simultaneously with nitrogen); 176.47 kg ha^{-1} of ammoniated single superphosphate; 40 kg ha^{-1} of FTE BR-10.

The plot was irrigated using a 3 CV motor pump set with a 1 inch diameter at the entrance and exit; a welded 25 mm PVC pipe; two AGROPOLO IS 30 ER sprinklers (nylon spindles) with nozzle nominal diameter = 4.0 × 3.0 mm and operating at a pressure of 30 pounds per square inch. Sprinklers were separated by 12 m, had an application intensity of 11.32 mm h^{-1}, and a wet diameter of 12 m. Irrigated water collection was quantified using pluviometers made with PET bottles (2 L capacity), centrally installed in the used areas of each plot, 1.50 m above the soil. Irrigation needs were determined following Rassini (2003), with the EPS (evaporation-plant-soil) use, based on evaporation in the class A tank and precipitation volume.

Irrigation was initiated when the ratio of evaporated to precipitated water volume was ≥25 mm, and continued until depth 4 (L4) reached 100% of available water (AW), with the remaining depths at 0% AW (L0), 21% AW (L1), 34% AW (L2), and 74% AW (L3). The field capacity (FC) and permanent wilting point (PWP) were obtained using Richards' extractor, determined with the moisture retention curve (VAN GENUCHTEN, 1980) as cited by (VANZELA; ANDRADE, 2007).

Water depth (WD, mm) differed in each cut depending on percent AW (L0–L4). In cut 1, WD was 1.22, 13.74, 26.88, 45.12, and 56.03; in cut 2, WD was 6.4, 48.01, 101.01, 304.94, and 601.78; finally in cut 3, WD was 4.57, 127.82, 234.92, 497.15, and 713.11.

The experiment was a randomized block design with five treatments (depths) and four replications. Each plot comprised four rows of elephant grass spaced 0.80 m with 5 m length, yielding 16 m^2 in total. The used area was 6.4 m^2 and included the two central rows, discounting 0.50 m at the edges.

Evaluated agronomic characteristics were plant height (cm, from soil surface up to height of the last exposed ligule), leaf blade percentage (leaf blade weight in relation to stem + leaf blade weight), and dry matter production (t ha^{-1}, dry mass cut close to the soil within the used area).

Standardization cuts to 10 cm above ground level were performed using a machete on January 23, 2007. Other cuts to the same height were performed every 60 days throughout March, May, July, and September 2007.

Forage production per plot was obtained from near-surface cuts of all plants in the used area (6.4 m^2). Samples were weighed in the field, on a scale with 100 g precision. Two representative sub-samples per plot were removed. A 10 tiller sub-sample was used to evaluate DM content, while another five-tiller sub-sample was used to determine agronomic characteristics (height, stem diameter, leaf blade percentage, and leaf/stem ratio).

Samples were ground in the Cattle Sector of the EAFC, using a Wiley mill with a 1 mm mesh sieve. Definitive DM at 105ºC was determined at the EAFC Microbiology Laboratory.

Data were subjected to ANOVA and regression in SAEG (1998), under the following statistical model:

$$Y_{ijk} = m + T_i + B_j + e_{ijk},$$

where

Y_{ijk} = value of kth plot under ith irrigation depth in the jth block;

m = general constant;

T_i = effect of ith irrigation depth;

B_j = effect of jth block;

e_{ijk} = random error of each observation.

Results and Discussion

March climatic conditions did not require irrigation (Table 1) and therefore the regression did not account for water depth. On average, sampled elephant grass during this period had the following characteristics: 6598.76 kg DM ha^{-1}, 72.41 cm height, 15.34 mm stem diameter, 49.72% leaf blade proportion, and 1.00 leaf/stem ratio. In May and July, irrigated water and DM production were linearly related ($P < 0.05$); DM production increased by 60.11 (May) and 7.43 kg ha^{-1} (July) with every 1.0 mm water applied (Figures 1a and 1b). Our results corroborated previous findings on irrigated elephant grass (TEIXEIRA et al., 2009). We also noted that irrigation water use was more efficient in May, probably because temperature, humidity, and solar radiation were all lower than in July. However, the minimum average temperature (20.4ºC) was still well above the lower basal temperature (13.9ºC) tolerated by elephant grass. Furthermore, soil water content was low in May, given that there was 132.1 mm of evaporation but only 33.2 mm of rainfall.

Table 1. Mean values of relative humidity (RH; %), maximum/minimum temperatures (ºC), rainfall (mm), and evaporation (mm) during the experiment.

Period	RH	Maximum temperature	Minimum temperature	Rainfall	Evaporation
January	82.00	34.0	24.0	458.1	80.0
February	81.00	32.5	23.5	913.0	40.0
March	78.00	33.4	23.4	171.5	99.2
April	77.00	34.4	22.5	18.0	81.8
May	73.00	31.0	18.2	33.2	132.1
June	66.00	32.2	17.1	0.0	29.5
July	68.00	31.2	16.5	62.3	97.3
August	58.00	32.8	15.7	0.0	140.2
September	62.00	35.9	22.0	9.5	117.9
October	72.00	35.2	22.9	142.0	120.4
November	81.50	33.0	21.3	147.8	105.3
December	80.00	33.5	21.8	146.7	92.8
Grand mean	73.21	33.3	20.7	175.1	94.7

Data from the Agro-climatic Station 83405/ 9º Distrito INMET/ EAFCáceres.

September cuts were of plants that grew during winter. Irrigation water levels exerted a quadratic effect ($P < 0.05$) on DM production, which reached a maximum of 3,500 kg ha^{-1} at a water depth of 577.65 mm (Figure 1). Similarly, a previous study on Napier grass and mombaça guinea grass found that irrigation resulted in higher DM yield than no irrigation (RIBEIRO et al., 2009).

Our data suggests that soil moisture is a limiting factor in elephant grass cv. Roxo production. May, July, and September cuts (without irrigation) had lower DM production than March and November cuts, periods that coincided with the end and beginning of the rainy season, respectively. A previous study obtained 9,200 kg DM ha^{-1} of elephant grass cv. Napier after regrowth for 56 days during spring (LIMA et al., 2007), lower than values found in the present work. When comparing the effect of irrigation water depth on DM production in dry periods (May, July, September), we observed that increased depth caused DM to rise by 193.61%, 519.81%, 375.20%, respectively, from DM at lower depth. Dry matter production observed in November cuts at L0 did not change as dramatically compared with L4 treatments. However, this relatively smaller difference probably resulted from nutrients accumulated during dry-period fertilization, which subsequently solubilized in rainwater.

May and September cuts exhibited a linear relationship between plant height and irrigation water levels ($P < 0.05$; Figure 2a and 2c); height increased by 0.3725 (May) and 0.0682 cm (September) for every 1.0 mm of water. In July, plant height and irrigation water had a quadratic relationship ($P < 0.05$), with a maximum height of 71.76 cm at a water level of 390.77 mm (Figure 2b).

Plant height and DM production were positively correlated (Figure 3), suggesting that the former can act as a proxy for the latter when evaluating elephant grass cv. Roxo productivity.

Figure 1. Estimated dry matter (DM) production (kg/ha) in elephant grass cv. Roxo as a function of water applied (mm) during irrigation. (a) May, (b) July, (c) September.

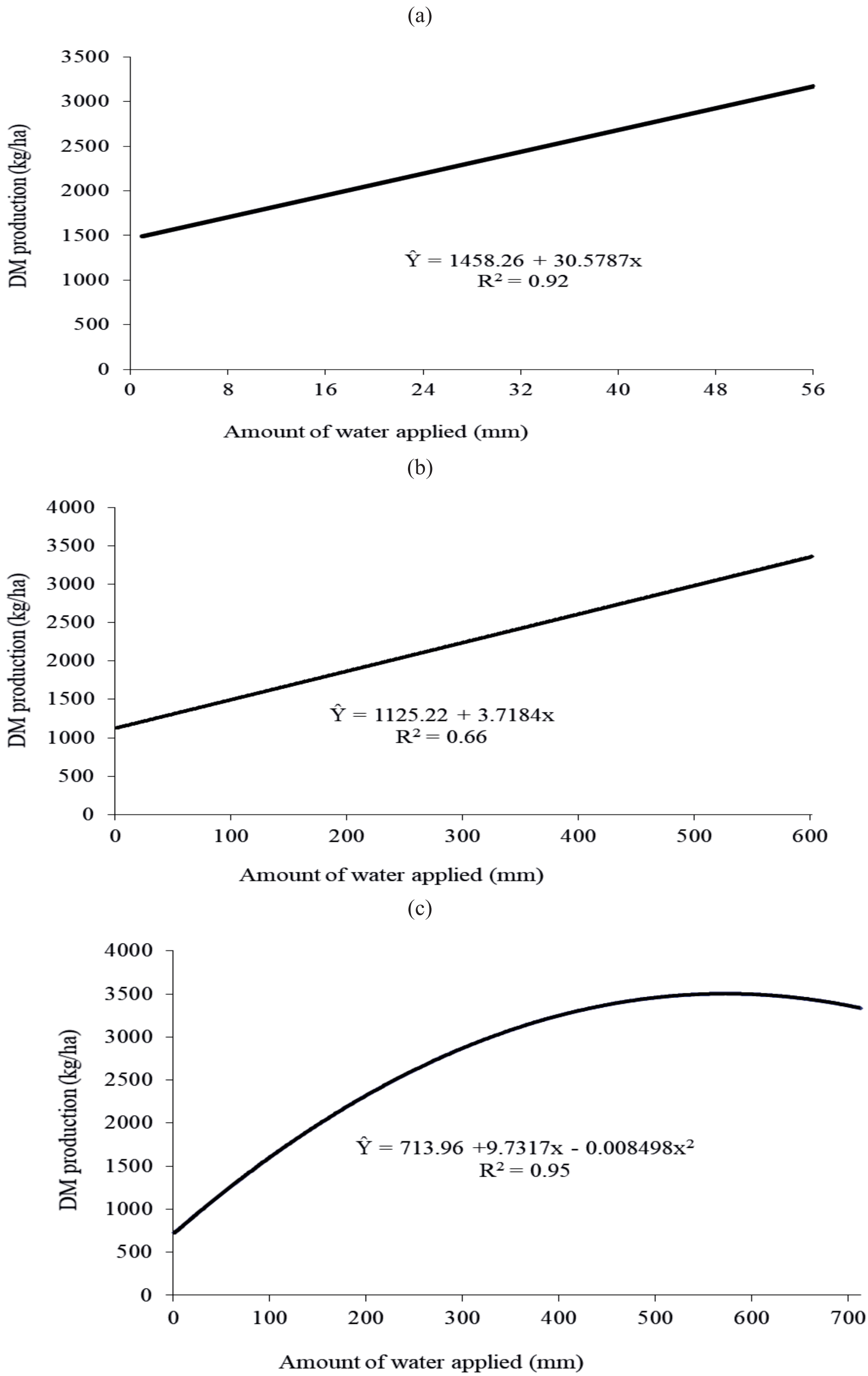
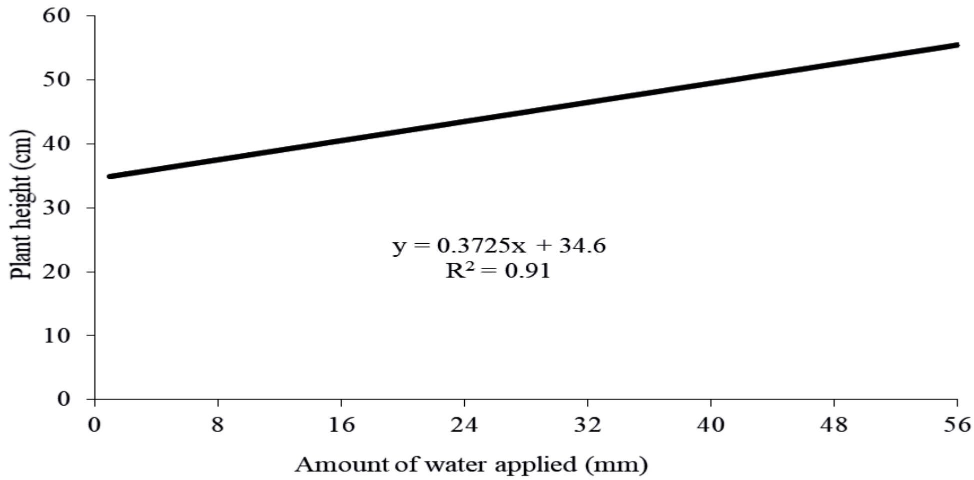
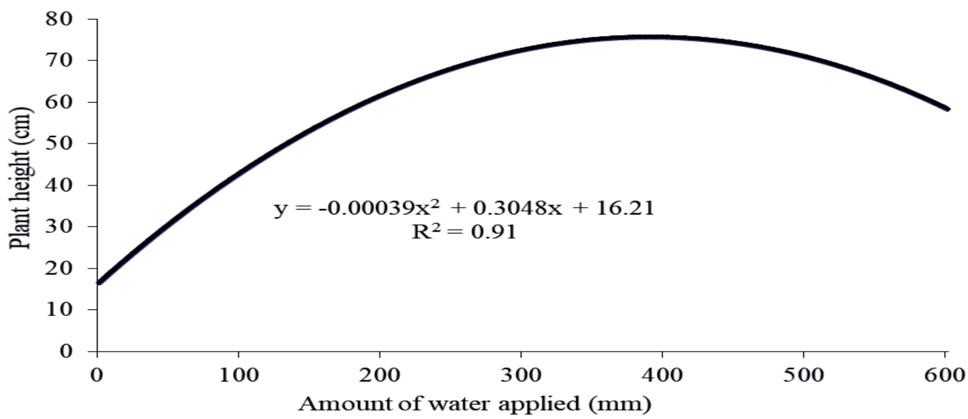


Figure 2. Estimated height (cm) of elephant grass cv. Roxo as a function of water applied (mm) during irrigation. (a) May, (b) July, (c) September.

(a)



(b)



(c)

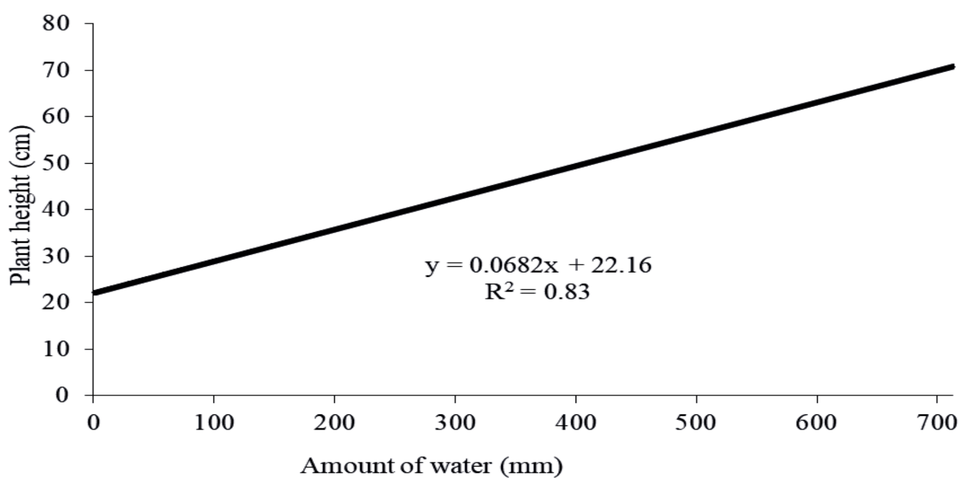


Figure 3. Relation between plant height (cm) and dry matter (DM) production (kg/ha).

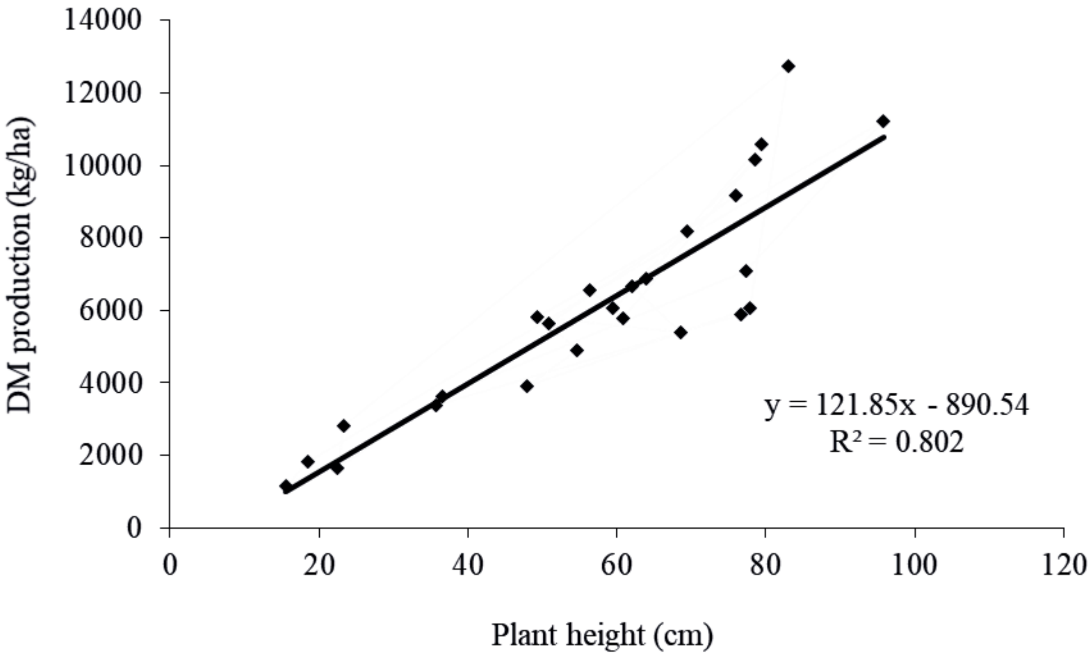


Figure 4 shows the percentage of elephant grass leaves as a function of water depth. Irrigation water was linearly and inversely ($P < 0.05$) related to the percentage of leaves from May, July, and September cuts; leaf percentage decreased by 0.0936%, 0.0295%, and 0.0122% in the three months, respectively, with every 1.0 mm increase in water levels (Figures 5a–c). This reduction in leaf proportion represents a decrease in the nutritive value of the forage because leaves generally have higher CP and lower NDF than stems (GOMIDE, 2001). In contrast to our results, however, a study on *B. brizantha* cv. Marandu did not find significant interactions between irrigation depth and nitrogen fertilization on leaf elongation rate (MAGALHÃES et al., 2016).

The inverse relationship between leaf percentage and irrigation resulted in a linear reduction ($P < 0.05$) of the leaf/stem ratio by 0.0047 (May), 0.0020 (July), and 0.00057 (September) units per 1.0 mm of irrigation water (Tables 2-4). Research on tanzania guinea grass found that pre-grazing leaf mass was higher under irrigation treatment; irrigation was able to prolong the grazing period (March, April) through its positive effects on grass during September and October) (SILVA et al., 2007).

Figure 4. Estimated leaf percentage in elephant grass cv. Roxo as a function of water applied (mm) during irrigation. (a) May, (b) July, (c) September.

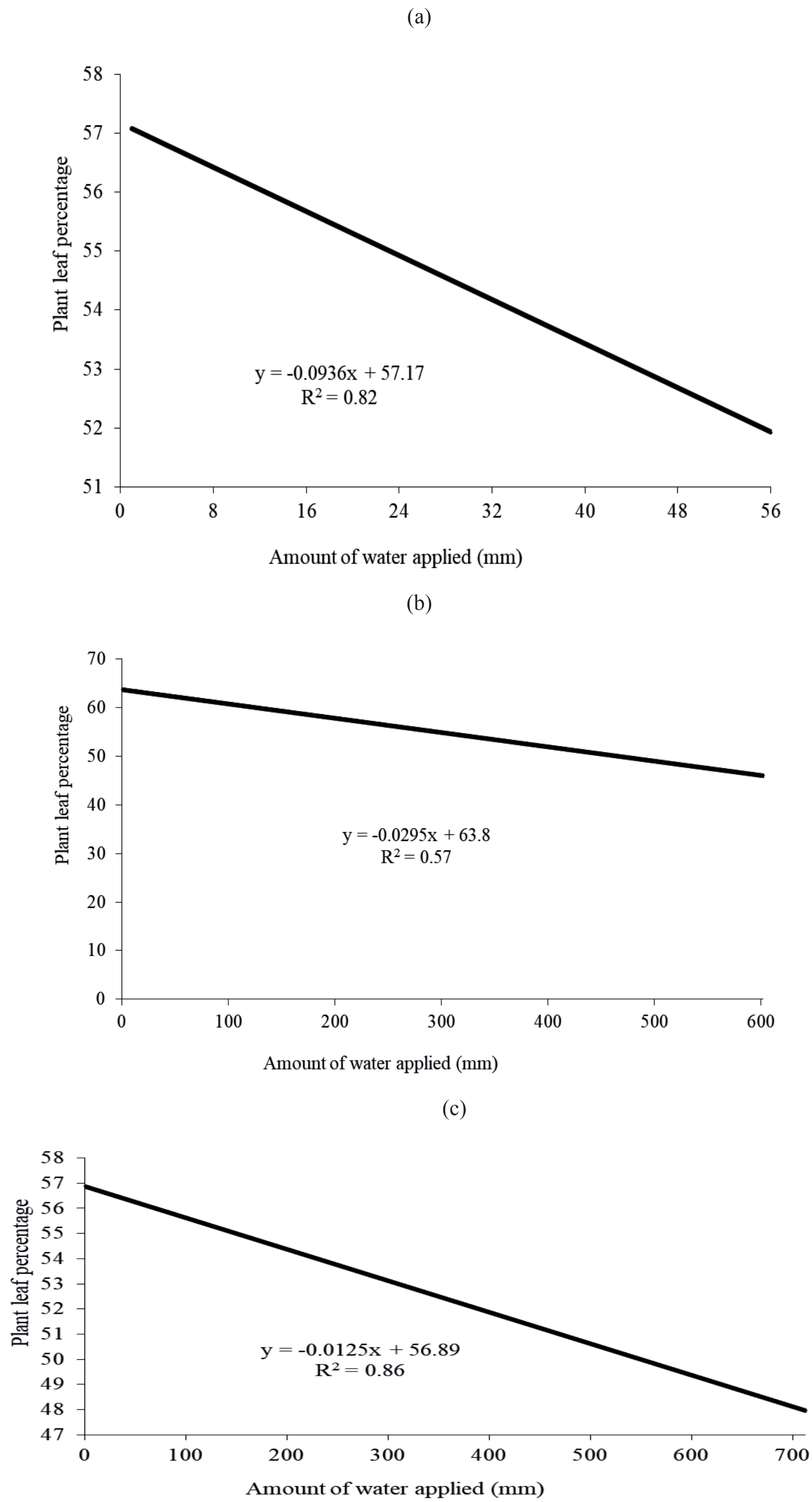


Table 2. Effect of irrigation water depth (WD, mm) on mean dry matter (DM) production (kg/ha), height (H, cm), and leaf percentage (L, %) of elephant grass (*Pennisetum purpureum* cv. Roxo) cut in May.

Variable	WD					Effect		CV
	1.22	13.74	26.88	45.12	56.03	L	Q	%
DM[1]	1696	1822	1955	2905	3284	0.0007	ns	25.77
H[2]	35.74	36.56	47.97	49.31	56.34	0.0007	ns	15.77
L[3]	55.99	57.21	54.82	53.27	51.24	0.009	ns	11.78

[1]$\hat{Y} = 2958.51 + 60.11\ X\ (R^2 = 0.91)$; [2]$\hat{Y} = 34.60 + 0{,}3725\ X\ (R^2 = 0.91)$; [3]$\hat{Y} = 57.17 - 0.0936\ X\ (R^2 = 0.82)$. L: linear effect, Q: quadratic effect, CV: coefficient of variation, ns: not significant.

Table 3. Effects of irrigation water depth (WD, mm) on mean dry matter (DM) production (kg/ha), height (H, cm), and leaf percentage (L, %) of elephant grass cv. Roxo cut in July.

Variable	WD					Effect		CV
	6.4	48.01	101.01	304.94	601.78	L	Q	%
DM[1]	582	820	2448	2694	3028	0.0000	ns	23.65
H[2]	15.55	22.44	54.64	68.66	59.44	0.0030	0.008	36.18
L[3]	6875	67.29	52.90	48.98	49.95	0.000	ns	11.02

[1]$\hat{Y} = 2261.64 + 7.426\ X\ (R^2 = 0.66)$; [2]$\hat{Y} = 16.21 + 0.3048\ X - 0.00039\ X^2\ (R^2 = 0.91)$;
[3]$\hat{Y} = 63.80 - 0.0295\ X\ (R^2 = 0.57)$. L: linear effect, Q: quadratic effect, CV: coefficient of variation, ns: not significant.

Table 4. Effects of irrigation water depth (WD, mm) on mean (DM) production (kg/ha), height (H, cm), and leaf percentage (L, %) of elephant grass cv. Roxo cut in September.

Variable	WD					Effect		CV
	4.57	127.82	234.92	497.15	713.11	L	Q	%
DM[1]	916	1405	2818	3438	3327.40	0.000	0.0023	20.21
H[2]	18.47	23.26	50.83	61.98	63.89	0.000	ns	17.57
L[3]	56.79	57.19	51.89	50.25	48.61	0.004	ns	17.09

[1]$\hat{Y} = 1427.92 + 19.64\ X - 0.0170\ X^2\ (R^2 = 0.95)$; [2]$\hat{Y} = 22.16 + 0.0682\ X\ (R^2 = 0.83)$
[3]$\hat{Y} = 56.89 - 0.01252\ X\ (R^2 = 0.86)$. L: linear effect, Q: quadratic effect, CV: coefficient of variation, ns: not significant.

Throughout plant development, the leaf/stem fraction of total DM decreases progressively as stem elongation intensifies. This gradual reduction in the leaf/stem ratio occurs because plants allocate more assimilates to reproductive portions at the expense of vegetative growth (MACHADO et al., 1984; FORMOSO, 1987; BARBOSA, 2003). The relevance of the leaf/stem ratio varies according to the forage species, being lower in plants with less lignified stems (GOMIDE; GOMIDE, 2001).

Conclusions

We demonstrated that increasing irrigation water depth increases DM and plant height in elephant grass cv. Roxo, cut every 60 days. Simultaneously, however, increasing water depth reduces leaf blade percentage and the leaf/stem ratio. Overall, we recommend irrigation as a management method to increase dry-season DM production in this major forage species of southwest Mato Grosso.

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