



ORIGINAL ARTICLE

## Establishment and biomass production of gamba and palisade grasses associated with pearl millet

### *Estabelecimento e produção de biomassa dos capins andropogon e marandu associado com milheto*

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#### KEYWORDS

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#### PALAVRAS-CHAVE

*Andropogon gayanus*  
Intercultivo  
*Pennisetum glaucum*  
*Urochloa brizantha*

**ABSTRACT:** The objective of this study was to evaluate the effects of pearl millet (*Pennisetum glaucum* (L.) R. Br) seeding rates (0, 5, 10, and 15 kg ha<sup>-1</sup>) in association with palisade (*Urochloa brizantha* (Hochst. ex A. Rich.) R.D. Webster cv. Marandu) and gamba (*Andropogon gayanus* Kunthvar. *Bisquamulatus* (Hochst.) Hack. cv. Planaltina) grasses on establishment parameters and forage biomass (FB) yield under low-input systems in Brazilian Cerrados. The experiment was conducted from December 2009 to April 2010, in Barreiras, Bahia, Brazil, using plots of 20m<sup>2</sup> (5 × 4m) under a randomized complete block design with four replications. The number of perennial grasses (NG) and millet (NM) seedlings were counted at 7<sup>th</sup>, 14<sup>th</sup>, 21<sup>st</sup>, and 28<sup>th</sup> day after sowing (DAS). The heights of perennial grasses (HG) and millet (HM) were measured at 48<sup>th</sup>, 73<sup>rd</sup>, 98<sup>th</sup>, and 125<sup>th</sup> DAS. On these dates, DM yield was quantified by harvesting the whole forage above 30cm. The increase in pearl millet seeding rate reduced NG and HG, while NM and HM increased. Association of pearl millet with grasses increased DM yield quadratically, with maximum point at the seeding rate of 6.5 kg ha<sup>-1</sup>. The presence of pearl millet affects the establishment and DM yield of palisade and gamba grasses, being recommended henceforth for reducing the first grazing event.

**RESUMO:** Objetivou-se com este estudo avaliar os efeitos da taxa de semeadura do milheto (*Pennisetum glaucum* (L.) R. Br) (0, 5, 10 e 15 kg ha<sup>-1</sup>) em associação com os capins marandu (*Urochloa brizantha* (Hochst. ex A. Rich.) R.D. Webster cv. Marandu) e andropogon (*Andropogon gayanus* Kunthvar. *Bisquamulatus* (Hochst.) Hack. cv. Planaltina) sobre os parâmetros de estabelecimento e rendimento de biomassa de forragem (BF) sob cultivo com baixa aplicação de insumos. O experimento foi conduzido de dezembro de 2009 a abril de 2010, em Barreiras, Bahia, utilizando parcelas de 20 m<sup>2</sup> (5 × 4 m) sob delineamento em blocos casualizados com quatro repetições. O número de plântulas dos capins (NC) e milheto (NM) foram contadas no 7º, 14º, 21º e 28º dia após emergência (DAE). As alturas dos capins (AC) e milheto (AM) foram medidas no 48º, 73º, 98º e 125º DAE. Nessas datas, a BF foi quantificada pela colheita de toda forragem acima de 30cm. O aumento da taxa de semeadura do milheto reduziu NC e AC, enquanto NM e AM aumentaram. A associação do milheto com os capins aumentaram o rendimento de MS quadraticamente, com o ponto de máximo na taxa de semeadura de 6,5 kg ha<sup>-1</sup>. A presença do milheto afeta o estabelecimento e o rendimento de MS dos capins marandu e andropogon, sendo recomendada doravante para antecipar o primeiro pastejo.

## 1 Introduction

Intercropping is usually defined as growing two or more crops together in the same land area at the same time (Brooker et al., 2015). It is a very widespread practice in the developing tropics that can often produce substantially higher yields than pure stand systems. One of the great features of intercropping is that this yield advantage can usually be achieved simply and cheaply, namely by growing crops together rather than separately (Li, 2016).

In low-input systems, intercropping increases biomass production as a result of the complementary use of resources such as nutrients and water and adaptation to sub-optimal environmental conditions (Franco et al., 2015), providing acceptable economic efficiency for farming enterprises (Peyraud et al., 2014; Huang et al., 2015).

Gamba grass (*Andropogon gayanus* Kunthvar. *Bisquamulatus* (Hochst.) Hack. cv. Planaltina) and palisade grass (*Urochloa brizantha* (Hochst. ex A. Rich.) R.D. Webster cv. Marandu) are two of the most common perennial grasses in Brazilian cerrados. The regular establishment of these grasses takes from 90 to 120 days after emergence (DAE) to set the cattle for the first grazing event. Their association with pearl millet, however, has reduced that period to 30 to 45 days DAE. Several studies have demonstrated the technical and economic viability of intercropping pastures with cereals (Lara-Cabezas, 2011; Mariani et al., 2012; Cruscio et al., 2013).

Pearl millet (*Pennisetum glaucum* (L.) R. Br) is a highly promising forage plant for both grain and forage production, because it has great biomass yield and high nutritional value

(Hill et al., 1999). Pearl millet may be used for recovery of degraded pastures and for anticipating the first grazing event. Pearl millet grows well in low-input systems, with a limited amount of water and nutrients (Uppal et al., 2015). However, there is no optimal seeding rate recommendation for its growth in an intercropping system. Recommendations only exist for single millet crop (10 to 25 kg ha<sup>-1</sup>) (Pitol et al., 1996).

In this context, the aim of the present study was to evaluate the effects of pearl millet seeding rates (0, 5, 10, and 15 kg ha<sup>-1</sup>) on some establishment parameters and forage biomass yield of palisade and gamba grasses under low-input systems in Brazilian savannas.

## 2 Material and Methods

The experiment was conducted in Barreiras-BA, Brazil (12°08'35" S, 44°57'33" W, and 495 m of altitude) from December 2009 to April 2010. According to the Köppen classification, the study area is under an Aw climate zone, a typical savanna with dry winters, with air temperature in the coldest month over 18°C, and an average annual precipitation of 1,200 mm.

The experiment was conducted in a total area of 640 m<sup>2</sup>. The area had more than 15 years without growing any crop, keeping natural fertility condition.

Soil samples were collected from the 0-30 cm layer, and then mixed and analyzed for the chemical properties (Table 1). No liming was necessary; the only fertilization consisted of single superphosphate (20% of P<sub>2</sub>O<sub>5</sub>) applied at sowing in the amount of 15 g of fertilizer per m<sup>2</sup>, equivalent to 30 kg of P<sub>2</sub>O<sub>5</sub> per hectare.

**Table 1.** Soil chemical properties of the experimental area (0 to 30 cm)

**Tabela 1.** Propriedades químicas do solo na área experimental (0 – 30cm)

pH	P	K	Ca <sup>2+</sup>	Mg <sup>2+</sup>	Al <sup>3+</sup>	H + Al	SB	CEC	V	
H <sub>2</sub> O	mg dm <sup>-3</sup>		-----cmol <sub>c</sub> dm <sup>-3</sup> -----							%
5.9	6.8	210.6	2.6	0.7	0.0	1.8	3.84	5.64	68.09	

CEC = cation exchange capacity; V = base saturation.

The soil was prepared with double disking, aiming to reach the depth of 30 cm. Thirty-two plots of 20 m<sup>2</sup> (5 × 4 m) were used, 1.0 m apart from each other. After excluding a border of 2 × 2 m, 6 m<sup>2</sup> (3 × 2 m) were left as testing area.

The experimental design was a randomized complete block following a 2 × 4 factorial arrangement (two perennial grass species and four pearl millet seeding rates), with four replications. Gamba (G) and palisade (P) grasses were used as perennial grasses. *Pearl millet* cv. Common seeding rates were 0, 5, 10, and 15 kg ha<sup>-1</sup>, using commercial grains as seed, forming the combinations G0, G5, G10, and G15; and P0, P5, P10, and P15 for gamba and palisade grasses, respectively.

Pearl millet grains used as seeds were obtained at a very low cost (US\$ 0.88 per kg). Then, the increase in establishment costs by applying the technique was only US\$ 4.40, 8.80, and 13.20 per hectare for the rates of 5, 10, and 15 kg ha<sup>-1</sup>, respectively.

For the grasses, certified seeds were acquired, and sowing rates were 3.3 and 3.7 kg of pure viable seeds for gamba and palisade grasses, respectively. The sowing process was carried out by broadcasting, and, then, seeds were incorporated into the soil using a rake to a depth of about 1 cm.

Precipitation and maximum, minimum, and average temperature data during the experimental period were collected daily in an automated station located 600 m from the experimental area (Figure 1).

Perennial grasses and pearl millet seedlings were counted at 7<sup>th</sup>, 14<sup>th</sup>, 21<sup>st</sup>, and 28<sup>th</sup> days after sowing (DAS). To facilitate the counting procedure, the experimental area was divided into twelve squares of 0.5 × 0.5 m (0.25 m<sup>2</sup>) using a string fixed to the ground with wooden sticks.

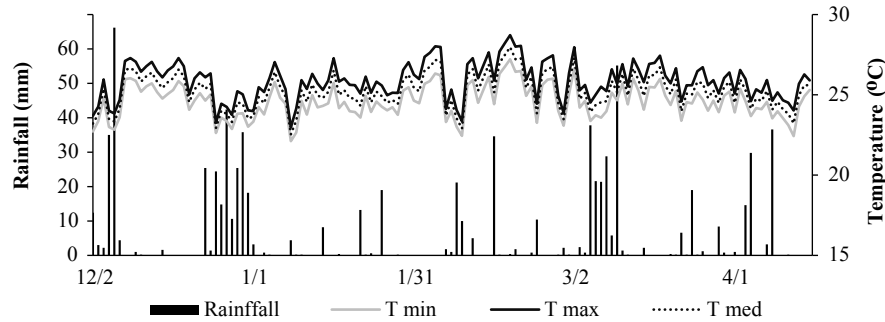
At 48<sup>th</sup> DAS, plots were harvested for the first time. The other harvests occurred at 73<sup>rd</sup>, 98<sup>th</sup>, and 125<sup>th</sup> DAS, in intervals of 25, 25, and 27 days, respectively. The plant harvesting height was above 30 cm and all biomass was collected. The material was weighed on a hanging digital scale with two decimal places. Then, an aliquot of approximately 500 g was used to determine dry matter concentration in a forced-air oven at 60°C for 72 h, and those values were used in the calculations of DM yield. The DM yield was determined as the sum of the four harvests.

The plant height was measured before the harvests using a transparency sheet on the plants, taking the mean values of the distance between the ground and four sides of the sheet.

From these four measurements, the average was taken as corresponding to each plot data.

Data were subjected to analyses of variance (ANOVA) twice. First, it was investigated the sources of variation: perennial grass, pearl millet seeding rate, and the interaction between them. The second analysis included the sources of variation:

treatment, time, and the interaction between them. In case of significance, an individual regression analysis was run, while combined regression analysis was performed if no significance was detected. In both cases, the models were subjected to an identity test, the t test, at 5% probability, using GENES software (version 2015.5.0).



**Figure 1.** Precipitation and minimum, maximum and medium temperature from December 2009 to April 2010

**Figura 1.** Precipitação e temperatura mínima, máxima e média de dezembro de 2009 a abril de 2010

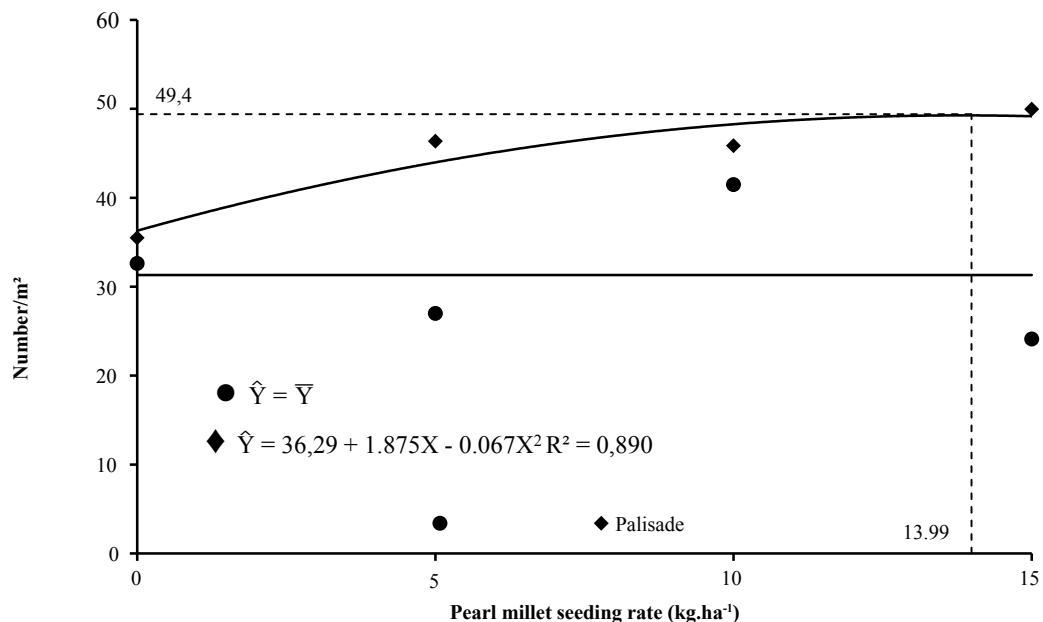
### 3 Results and Discussion

The number of palisade grass seedlings according to the increasing millet rates showed a quadratic response (Figure 2). The maximum number of palisade seedlings per square meter (49 plants) was obtained with the pearl millet seeding rate of 14 kg. This value was greater than the average number of gamba grass seedlings (31 plants), which was not statistically affected by the intercropping.

Apparently, the use of up to 15 kg ha<sup>-1</sup> of millet seeds did not compromise the establishment of palisade and gamba grasses (Figure 2). The maximum pearl millet seeding rate tolerated by

palisade grass contrasted Pitolo et al. (1996), who recommended between 15 and 20 kg ha<sup>-1</sup> as single crop or 2 until 3 kg ha<sup>-1</sup> intercropped with *Uroclora* spp. However, Maia et al. (2000) suggested that new experiments should use seeding rates exceeding 5 kg ha<sup>-1</sup>.

The density of perennial grasses seedlings (NG) increased linearly up to 28 DAS, except for treatments G10 and P5, which showed a quadratic effect (Table 2). The maximum values for these treatments were 41.5 and 44.9 plants/m<sup>2</sup> for 23 and 24 days after sowing (DAS), respectively.



**Figure 2.** Density of seedlings of gamba and palisade grasses sown associated with pearl millet

**Figura 2.** Densidade de plântulas dos capins andropogon e marandu em plantio associado com milheto

After germination had started, there was a water stress that persisted until 21 days after sowing. The lack of rain delayed the seed germination of gamba grass and also caused the death of seedlings that had already emerged. In comparison, palisade grass was not deeply affected, as this cultivar has a relatively larger seed, which provides greater nutrient reserves, and thus a rapid initial development.

According to Veras et al. (2010), the gamba grass has a slow initial growth until the plants reach 15 to 20 cm, a characteristic that benefits the formation of pastures associated

with annual grain crops, forest species, and forage legumes. On the other hand, in well-prepared soil without weeds, pearl millet will emerge rapidly and grow quickly (Hill et al., 1999).

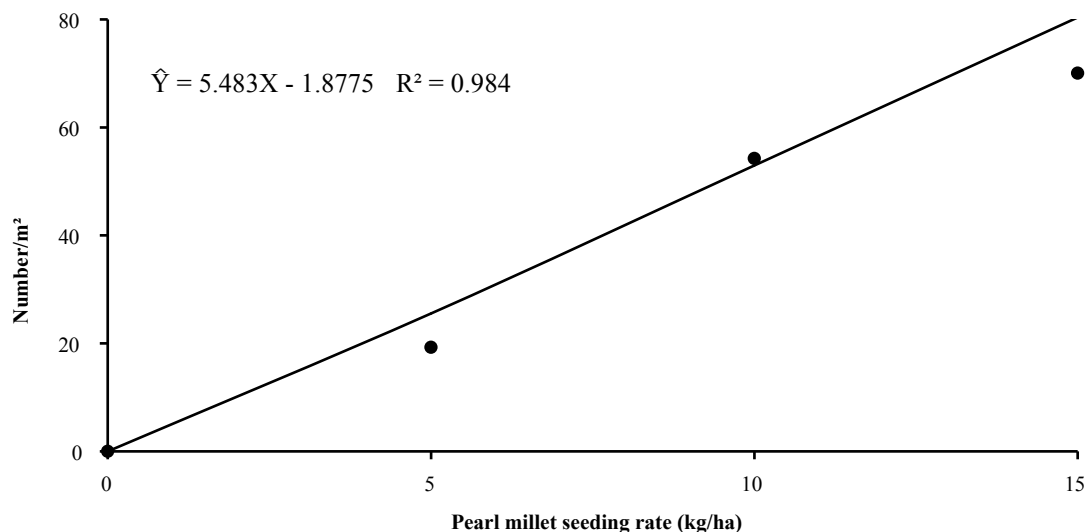
At 28<sup>th</sup> DAS, both perennial grasses had a seedling density greater than 20 seedlings per square meter, the minimum recommended by Castagnara et al. (2011) for medium-sized seeds species, such as *Urochloa* spp., to ensure good pasture establishment.

As expected, the pearl millet seedling density increased linearly ( $R^2 = 0.984$ ) with the increase in seeding rate (Figure 3).

**Table 2.** Models adjusted for density of seedlings of gamba and palisade grasses intercropped with pearl millet as a function of days after sowing

**Tabela 2.** Modelos ajustados para densidade de plântulas dos capins andropogon e marandu consorciados com milheto em função dos dias após a semeadura

Treatment	Model	R <sup>2</sup>	Maximum (x,y)
G0 (Gamba exclusive)	= 26.06 + 0.241*X	0.814	
G5 (Gamba + 5 kg millet)	= 20.18 + 0.339**X	0.977	
G10 (Gamba + 10 kg millet)	= 21.81 + 1.660**X - 0.035**X <sup>2</sup>	0.998	(23.7; 41.5)
G15 (Gamba + 15 kg millet)	= 19.31 + 0.155**X	0.908	
P0 (Palisade exclusive)	= 24.02 + 0.431**X	0.955	
P5 (Palisade + 5 kg millet)	= 5.093 + 3.222**X - 0.065**X <sup>2</sup>	0.997	(24.8; 44.9)
P10 (Palisade + 10 kg millet)	= 30.68 + 0.560**X	0.968	
P15 (Palisade + 15 kg millet)	= 43.89 + 0.117*X	0.780	



**Figure 3.** Density of pearl millet seedlings when intercropped with gamba and palisade grasses

**Figura 3.** Densidade de plântulas de milheto em plantio associado com os capins andropogon e marandu

Comparing the Figures 2 and 3, it can be noted that from the seeding rate of 10 kg ha<sup>-1</sup> onwards the pearl millet seedlings count exceeded the palisade and gamba grasses seedlings density. In this regard, there was no significant interaction between the number of pearl millet seedlings (NM) and evaluation dates.

The perennial grasses height (HG) decreased with the increase in pearl millet seeding rate, with both species fitting decreasing linear models (Figure 4). Compared with the single stand, the use of 15 kg.ha<sup>-1</sup> of pearl millet caused

a reduction of about 25% and 24% for palisade and gamba grasses, respectively.

Palisade grass was taller (68.8cm) compared with gamba grass (60.3cm) when grown as single crop (Figure 4). However, at the maximum pearl millet seeding rate (15 kg.ha<sup>-1</sup>), the grasses showed close height values: 46.4 and 51.5cm for gamba and palisade grasses, respectively.

The presence of millet had a similar effect on HG during the study period, in which all treatments fitted increasing linear models (Table 3). At 48 DAS, there was practically no difference

between the HG of all treatments. The rate of 15 kg ha<sup>-1</sup> of millet seeds reduced HG significantly from 78 DAS. In the last harvest (125 DAS), G15 was 33% shorter than G0, while the other treatments were similar ( $p > 0.05$ ).

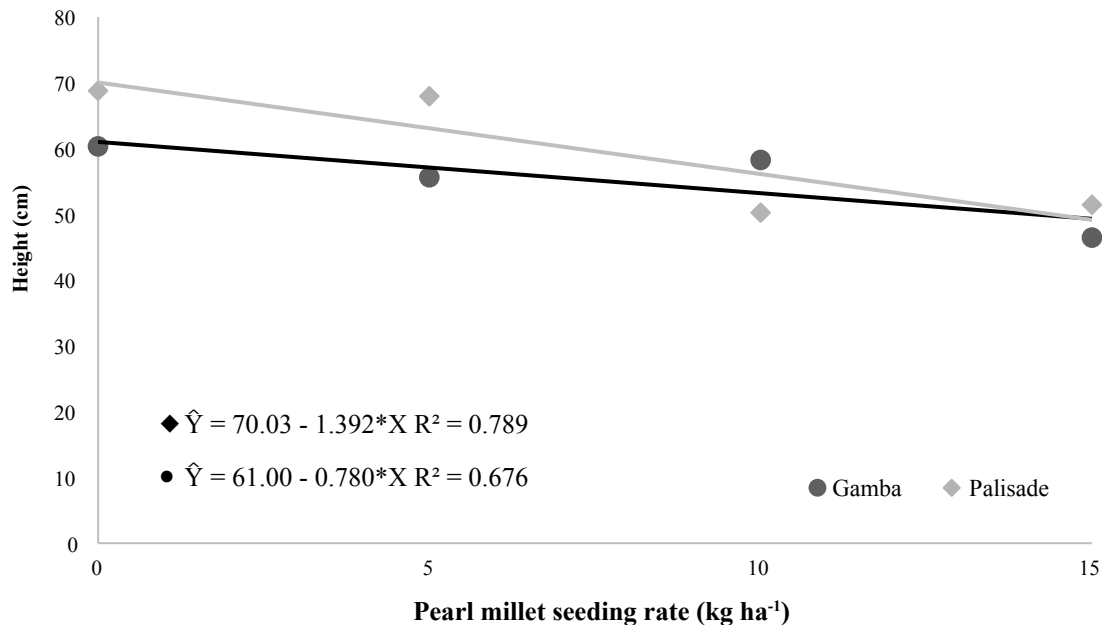
Regarding HG, the same response pattern was not observed in either gamba or palisade grass, in which initially the lowest pearl millet seeding rates did not influence the results (Table 3). In P10 and P15, HG decreased over time, mainly from 72 DAS. At the end of the evaluation, the use of 10 kg ha<sup>-1</sup> pearl millet affected HG ( $p < 0.05$ ), while absence or 5 kg ha<sup>-1</sup> of millet did not cause differences ( $p > 0.05$ ).

There was no significant interaction between pearl millet seeding rate and perennial forage grass species on average pearl millet height (HM). The grass species did not influence

this trait. However, a significant response of millet sowing rate was observed on HM ( $p < 0.01$ ), which responded in a quadratic manner ( $R^2 = 0.972$ ) (Figure 5). The maximum HM (95.1cm) was obtained at the seeding rate of 10.6 kg ha<sup>-1</sup>.

The maximum height of pearl millet plants was observed between 80 and 90 DAS, especially in treatments G10 of millet (116cm) and P5 (118cm).

Competition for light involves differences in the ability of plants to place their leaves above the adjacent plants in the pasture. According to Griffith et al. (2016), if a plant has a great proportion of shaded leaves, its net energy gain by photosynthesis may be lower than the respiratory energy required for tissue maintenance. Interspecific competition can influence the growth habit of the species, causing a more upright growth (Turcotte & Levine, 2016).



**Figure 4.** Average height of gamba and palisade grasses intercropped with pearl millet

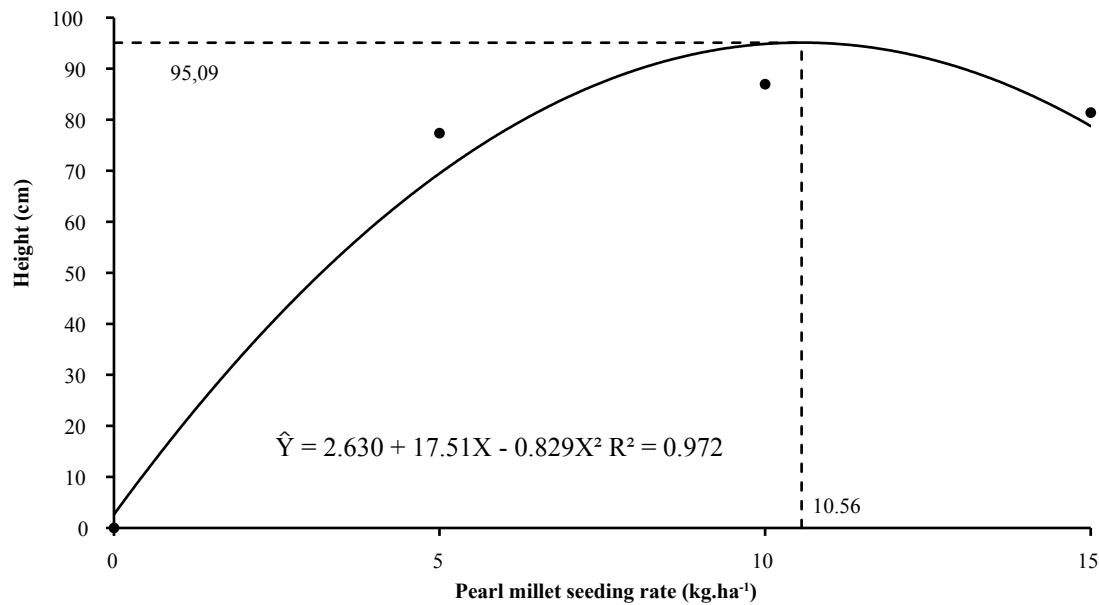
**Figura 4.** Altura média dos capins andropogon e marandu plantados associadamente com milheto

**Table 3.** Models adjusted by height of gamba and palisade grasses intercropped with pearl millet as a function of days after sowing

**Tabela 3.** Modelos ajustados para altura de plantas dos capins andropogon e marandu consorciados com milheto em função dos dias após a semeadura

Treatment	Model	R <sup>2</sup>
G0 (Gamba exclusive)	= - 32.56 + 1.079**X	0.926
G5 (Gamba + 5 kg millet)	= - 36.72 + 1.073*X	0.818
G10 (Gamba + 10 kg millet)	= - 42.58 + 1.172*X	0.875
G15 (Gamba + 15 kg millet)	= - 6.072 + 0.610**X	0.965
P0 (Palisade exclusive)	= - 22.64 + 1.062**X	0.981
P5 (Palisade + 5 kg millet)	= - 16.20 + 0.978**X	0.906
P10 (Palisade + 10 kg millet)	= - 3.224 + 0.621*X	0.816
P15 (Palisade + 15 kg millet)	= - 19.64 + 0.826**X	0.957





**Figure 5.** Height of pearl millet plants intercropped with gamba and palisade grasses as a function of pearl millet seeding rate  
**Figura 5.** Altura de plantas de milheto interplantadas com gramíneas gamba e palissada em função da taxa de sementeira do milheto

There was an interaction between treatment and time ( $p < 0.01$ ). All treatments fitted a quadratic model, except for the perennial grasses grown as single crop (Table 4).

Conflicting with our findings, Thier et al. (2012) found that *U. brizantha* and *U. ruziziensis* intercropped with sorghum were taller in relation to their monocultures. The authors attributed this behavior to the influence of shading caused by the sorghum plants on the perennial grasses, making them taller due to etiolating in the search for sunlight searching.

According to Cruz et al. (2008), *Urocloa decumbens* has limited growth when intercropped with corn, due to the effect of shade caused by the cereal. Thus, considering its inherent traits, pearl millet showed less light competitive interaction with the perennial grasses than corn or sorghum, thus being an option to be considered in intercropping systems for either grain or forage.

Another effect related to competitiveness is thinning, in which there is a tendency for some plants to die as their neighbors increase in weight. This density-related mortality may not

occur until some weeks after establishment, and its onset is earlier at a high population density and may start earlier in some species (Pearson & Ison, 1997).

On the other hand, according Mobasser et al. (2014), intercropping can conserve soil water by providing shade, reducing wind speed and increasing infiltration with mulch layers and improved soil structure.

The reduction of HG when pearl millet seeding rates above 10 kg.ha<sup>-1</sup> were used was likely due to interspecific competition. Under these conditions, the population of pearl millet per hectare exceeded 500,000, which is much greater than the 100,000 to 175,000 plants/ha<sup>-1</sup> recommended for grain production in single crop (Andrews et al., 1993).

The height values of pearl millet plants over time were below those obtained by Spehar & Trecenti (2011), who evaluated two growth seasons (between 173 and 204cm). These authors attributed the successful development of plants to the high soil fertility, after liming and fertilization with 640 kg.ha<sup>-1</sup> NPK (4-14-8), in addition to adequate water supply.

**Table 4.** Models adjusted by height of pearl millet during establishment of pasture when intercropped with gamba and palisade grasses

**Tabela 4.** Modelos ajustados para altura do milheto durante o estabelecimento da pastagem quando consorciado com os capins andropógon e marandu

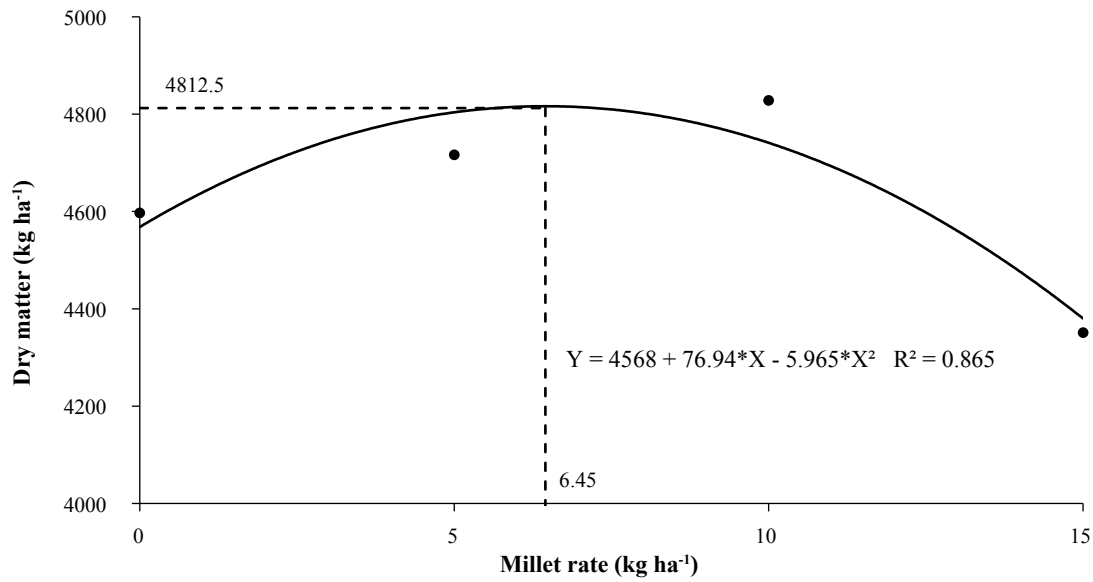
Treatment	Model	R <sup>2</sup>	Maximum (x,y)
G0 (Gamba exclusive)			
G5 (Gamba + 5 kg millet)	= - 111.6 + 5.068*X - 0.029*X <sup>2</sup>	0.756	(87.38; 109.82)
G10 (Gamba + 10 kg millet)	= - 135.4 + 5.393**X - 0.029**X <sup>2</sup>	0.993	(92.98; 115.51)
G15 (Gamba + 15 kg millet)	= - 80.64 + 4.686**X - 0.029**X <sup>2</sup>	0.978	(80.79; 108.66)
P0 (Palisade exclusive)			
P5 (Palisade + 5 kg millet)	= - 209.7 + 8.013**X - 0.049**X <sup>2</sup>	0.989	(81.76; 117.89)
P10 (Palisade + 10 kg millet)	= - 140.8 + 6.424**X - 0.039**X <sup>2</sup>	0.999	(82.36; 97.41)
P15 (Palisade + 15 kg millet)	= - 32.73 + 3.174**X - 0.019**X <sup>2</sup>	0.963	(83.50; 99.82)

Interestingly, for FB yield, there was no significant difference between seeding rates of grasses and pearl millet, and neither was there an interaction between the two factors ( $p>0.05$ ). However, there was a trend towards a quadratic response ( $R^2 = 0.865$ ) in FB yield when pearl millet seeding rate was increased (Figure 6). In this way, the maximum FB yield (4,812 kg) was obtained with the millet seeding rate of 6.45 kg.ha<sup>-1</sup>.

Through individual analysis of treatments for FB, significance was found for the interaction between treatment

and harvest time ( $p<0.05$ ). The FB yield of all treatments fitted quadratic models, except for single gamba grass, which had an average yield of 863 kg.ha<sup>-1</sup> and the treatment G10, which responded linearly to pearl millet seeding rates (Table 5).

In the first harvest, the FB yield of the perennial grasses, as a single crop, was zero, because they did not reach 30cm, which was the previously set harvesting height. Overall, palisade grass with pearl millet had greater forage production.



**Figure 6.** Forage biomass yield of forage of gamba and palisade grasses intercropped with pearl millet

**Figura 6.** Biomassa de forragem dos capins andropogon e marandu plantados em associação com milho

**Table 5.** Models adjusted by forage biomass of gamba and palisade grasses as a function of days after sowing, when intercropped with pearl millet  
**Tabela 5.** Modelos ajustados pelo rendimento de biomassa de forragem dos capins andropogon e marandu em função dos dias após a semeadura, quando consorciados com milho

Treatment	Model	R <sup>2</sup>
T1 (Gamba exclusive)	= 862.28	
T2 (Gamba + 5 kg millet)	= 1.910 – 55.94**X + 0.466**X <sup>2</sup>	0.914
T3 (Gamba + 10 kg millet)	= - 550.7 + 19.93*X	0.846
T4 (Gamba + 15 kg millet)	= 3.832 – 89.53*X + 0.619*X <sup>2</sup>	0.833
T5 (Palisade exclusive)	= 708.4 – 38.92**X + 0.496**X <sup>2</sup>	0.999
T6 (Palisade + 5 kg millet)	= 560.6 – 15.57**X + 0.268**X <sup>2</sup>	0.992
T7 (Palisade + 10 kg millet)	= 2.002 – 38.41**X + 0.310**X <sup>2</sup>	0.938
T8 (Palisade + 15 kg millet)	= 2.304 – 55.78*X + 0.419*X <sup>2</sup>	0.874

Gamba grass had a higher FB yield with the increase in pearl millet seeding rate. This response was more evident at 48 and 73 DAS, corresponding to the first and second harvests, respectively. From the third harvest (98 days DAS) onwards, the FB yield among the treatments was almost equaled, although in the last harvest control treatment produced more FB than the others. At that time, pearl millet had lost its regrowth capacity.

The slow initial development of gamba grass facilitated its establishment in intercropping with pearl millet (Veras et al., 2010). By contrast, pearl millet had a quick initial development, accumulating FB in a shorter time that allowed the anticipation of grazing. This aspect is important in establishing pastures, because it contributes to lowering the high initial costs. In addition, initial grazing in newly established pasture stimulates lateral growth, and tillering and should be performed when plants have reached

a compatible development with the size of the species, with a high stocking rate and in the short-term, to mitigate the harmful effects of defoliation and cattle trampling on the forage. The animal exerts its power of selection by grazing first the high-quality millet herbage (Andrews & Kumar, 1992); therefore, the perennial grass will be preserved without much disturbance on its establishment.

Unlike gamba grass, palisade grass had its biomass yield decreased with the increasing pearl millet seeding rates, demonstrating it is subject to deleterious effects from competition. This was unexpected, considering the capacity of palisade grass in being dominant in non-native areas due to the allelopathic effect of phytotoxic substances (Kato-Noguchi et al., 2014).

The pearl millet was essential for increasing forage biomass earlier, mainly in the first and second harvests, when the grasses had not grown enough to produce harvestable forage. In two first harvests, the treatments with 10 and 15 kg.ha<sup>-1</sup> pearl millet were those that produced most FB, or at least the same amount as the other treatments. However, in the third harvest, forage production was almost equalized among all treatments, although in fourth harvest the opposite effect occurred, and treatments with exclusive grasses and grass intercropped with 5 kg.ha<sup>-1</sup> of pearl millet were more productive.

According to Lara-Cabezas (2011), crops of greater vegetative growth, such as corn and millet, can inhibit the growth of the associated perennial forage plant. Cruz et al. (2008) observed that in intercropping corn and *U. decumbens*, the cereal affected the development of the perennial forage plant, which showed slower initial growth, when compared with the development of *U. decumbens* grown as a single crop.

The relative maturity of the annual crop can affect the degree and length of competition and, thus, the success of intercropping systems. According to Crusciol et al. (2013), compared with earlier hybrids of corn, later hybrids decreased FB yield of palisade grass probably by the reduction of incidence of light on the canopy leaves and the amount of water intercepted from the rain after the grains harvest. Furthermore, corn yield was also impaired, which was not observed when earlier hybrids were used.

Studying the technical feasibility of the intercropping between of grain crops —soybeans and maize— and palisade grass and *Panicum maximum* (Mombaça and Aruana), Mariani et al. (2012) found that FB accumulation, at 132 DAS, was higher for palisade grass.

The use of 10 and 15 kg.ha<sup>-1</sup> of millet in the establishment provided a greater FB yield in the first harvest (78 DAS), a relevant aspect to anticipate the use of pasture, as discussed previously. In the second harvest, the FB yield was practically equal among the different treatments, and in the subsequent harvests, palisade grass grown as single crop or intercropped with 5 kg.ha<sup>-1</sup> of pearl millet seeds outdid the others.

Pearl millet associated with perennial grasses was considered an interesting option to increase FB yield in a short period and provide high-forage quality to the cattle, as attested by Hill et al. (1999). Nevertheless, the anticipation of grazing and live gain weight should be considered in the production systems.

## 4 Conclusions

The establishment of gamba and palisade pastures intercropped with pearl millet is a viable alternative to increase forage biomass

yield. Therefore, the intercropping may allow the anticipation of pasture use without compromising the establishment of gamba and palisade grasses as long as the seeding rate is below 6.5 kg.ha<sup>-1</sup>.

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