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Production in forage sorghum intercropped with grasses and pigeon pea at crop cutting[1]

Produção de sorgo forrageiro consorciado com gramíneas e guandu-anão no corte da safra

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ABSTRACT - Due to the need to implement sustainable systems of high productivity for farming, the aim of this study was to evaluate the agronomic characteristics of forage sorghum (*Sorghum bicolor* (L.) Moench) intercropped with *Urochloa brizantha*, *Megathyrsus maximum* and/or pigeon pea in a non-irrigated area of a low-altitude region of the Cerrado. A randomised block design was used, of plots split over time with six treatments and four replications over two agricultural years. The treatments were (I) monocropped forage sorghum, and forage sorghum intercropped with (II) *U. brizantha*, (III) *M. maximum*, (IV) *U. brizantha* and pigeon pea, (V) *M. maximum* and pigeon pea, and (VI) pigeon pea. The following were evaluated in the sorghum and its respective intercrops: plant height, stem diameter, stand and productivity. Intercropping sorghum with *M. maximum* reduced fresh and dry matter production in the sorghum, albeit with no significant effect on total dry matter production for the intercrop. Sorghum intercropped with *M. maximum* gave a higher percentage of panicles than the other intercropped systems.

Key words: *Cajanus cajan*. *Megathyrsus maximum. Urochloa brizantha.*

RESUMO - Devido à necessidade de implantação de sistemas sustentáveis e de alta produtividade na agropecuária, objetivou-se avaliar as características agronômicas do sorgo (*Sorghum bicolor* (L.) Moench) forrageiro consorciado com o *Urochloa brizantha*, *Megathyrsus maximum* e/ou guandu-anão em região de Cerrado de baixa altitude, em área não irrigada. Utilizou-se o delineamento em blocos casualizados, em parcela subdividida no tempo com seis tratamentos e quatro repetições durante dois anos agrícolas. Os tratamentos utilizados foram (I) sorgo forrageiro em monocultivo e consorciado com: (II) *U. brizantha*; (III) *M. maximum*; (IV) *U. brizantha* e guandu-anão; (V) *M. maximum* e guandu-anão; e (VI) guandu-anão. Foram avaliadas a altura de plantas, o diâmetro do colmo, o estande de plantas e a produtividade do sorgo e seus respectivos consórcios. Os consórcios de sorgo com *M. maximum* reduziram a produtividade de massa verde e seca do sorgo, entretanto sem efeito significativo na produtividade de massa seca total do consórcio. O sorgo consorciado com *M. maximum* proporcionou maior porcentagem de panícula que os demais consórcios.

Palavras-chave: *Cajanus cajan*. *Megathyrsus maximum*. *Urochloa brizantha.*

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INTRODUCTION

Intercropping grain crops with grasses is the basis of the Integrated Farming Production System (IFPS), and seeks to improve benefits for the soil, plants, and animals. This type of integration is advantageous, as it benefits agricultural and livestock activities, offering gains to the producer. Such systems have been the object of study in various regions of the world to promote technological innovation in agricultural activities (CARVALHO *et al*., 2010).

For Lanzanova *et al*. (2007), many producers are afraid to adopt this system due to a lack of knowledge of the correct establishment and management of crops when grown in an intercropped system. According to Miranda *et al*. (2010), among the various options, the use of sorghum for forage production has taken on an increasingly important role in recent years, both in Brazil and worldwide, as its resistance to adverse environmental factors is well known compared to maize, which is the most popular crop for silage production. Sorghum also offers high dry-matter productivity per area, a good fermentation pattern, and high nutritional value, both in the production of silage and supplying fresh feed to ruminants.

The regrowth ability of sorghum is another great advantage in intensive production systems, as after harvesting the grain or shoots, a new harvest is possible without the need to replant the crop. It is also possible to manage crop regrowth for grazing in IFPS programs, or to use the straw produced from plant regeneration as ground cover in an on-going no-till system (FOLONI *et al*., 2008).

Several studies have demonstrated the technical viability of intercropping forages with cereals (CARVALHO *et al*., 2011), however, variations in the results from different regions of Brazil highlight the importance of regionalised research. It is therefore necessary to understand the interactions and interference that occur when intercropping sorghum with forage grasses, and identify which species best adapts to intercropping in low-altitude regions of the Cerrado.

The aim of this study was to evaluate the agronomic characteristics of forage sorghum as a monocrop and intercropped with *U. brizantha* 'Marandu', *M. maximum* 'Mombasa' and/or pigeon pea, in an integrated farming production system in a low-altitude region of the Cerrado, over two agricultural years.

MATERIAL AND METHODS

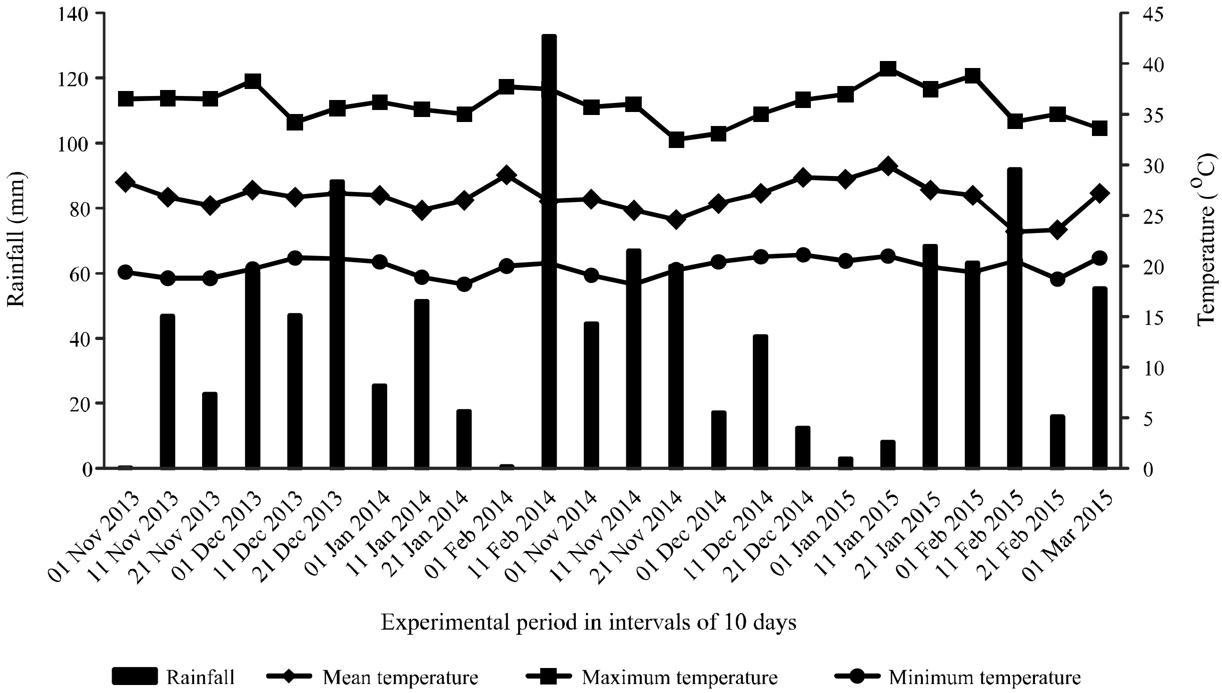
The experiment was conducted in a non-irrigated area of the Plant Production Sector at the Teaching, Research and Extension Farm (FEPE) of the Ilha Solteira School of Engineering (FEIS/UNESP), in Selvíria, Mato Grosso do Sul (MS) (20°18' S and 51°22' W, altitude 370 m). According to the Köppen classification, the climate in the region is type Aw, humid tropical with a rainy season during the summer and dry season during the winter. The rainfall data, and the maximum, minimum and mean temperatures (Figure 1) were recorded daily by an automatic weather station installed about 500 m from the experimental area.

The treatments were carried out during the 2013/2014 and 2014/2015 agricultural years, using a randomised block design of plots split over time, with six treatments and four replications, giving a total of 24 plots with a width of 2.92 m and length of 20 m total area per plot. The treatments were set up during the first (2013) and second year (2014), on the 8 th and 4 th of November respectively. In the second year (2014/2015), the experiment was set up in the same area as the plot of the previous year. The treatments under evaluation were (I) monocropped forage sorghum, and forage sorghum intercropped wit: (II) *U. brizantha* 'Marandu', (III) *M. maximum* 'Mombasa', (IV) *U. brizantha* 'Marandu' and pigeon pea, (V) *M. maximum* 'Mombasa' and pigeon pea, and (VI) pigeon pea.

The soil of the experimental area was classified as a typical clayey Red Latosol (EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA, 2013). To characterise the soil before setting up the experiment (8 Nov 2013), an analysis of the chemical quality was carried out as per the methodology proposed by Raij *et al*. (2001), where the following values were found in the 0 to 0.10 m layer: resin P (mg dm^{-3}) of 62; OM (g dm^{-3}) of 21; pH in $CaCl_2$ of 4.8: K, Ca, Mg, H+Al and Al (mmol$_c$ dm^{-3}) of 1.6, 12, 10, 38 and 3 respectively; S-SO4 of 5 mg dm^{-3}; V% of 38; and Cu, Fe, Mn and Zn of 2.6, 26, 21 and 1.2 mg dm^{-3} respectively. In the 0.10 to 0.20 m layer, the values were: resin P (mg dm^{-3}) of 17; OM (g dm^{-3}) of 16; pH in $CaCl_2$ of 4.4; K, Ca, Mg, H+Al and Al (mmol$_c$ dm^{-3}) of 1, 7, 6, 47 and 8 respectively; S-SO4 of 15 mg dm^{-3} and V% of 23.

The species under study were sown in rows 0.45 m apart, with the sorghum and forage grasses sown in the same row and the pigeon pea between the rows. The sorghum was sown mechanically at a depth of approximately 0.05 m and 15 seeds per metre by means of a planter-fertiliser with a rod-like furrowing mechanism (blade) for direct planting. The forage grasses were sown together with the sorghum, mixing the seeds with the fertiliser immediately prior to planting, with the aim of delaying emergence and reducing the probable competition between species during the initial period of development. For the first year, 13.3 kg ha^{-1} marandu grass seed (PLS = 36%) and 14.4 kg ha^{-1} mombasa grass

Figure 1 - Climate data shown for intervals of ten days, from November 2013 to February 2014 and November 2014 to March 2015, collected at the FEPE weather station. Selvíria MS



Source: prepared by the author

seed (PLS = 25%) were used, and in the second year 9.6 kg ha^{-1} marandu grass (PLS = 50%) and 10.3 kg ha^{-1} mombasa grass (PLS = 35%). The pigeon pea was sown immediately after the sorghum/ forage grasses, at a depth of 0.06 m and 20 seeds per metre, using a different planter-fertiliser.

For each agricultural year (2013/2014 and 2014/2015), 300 kg ha^{-1} formula 08-28-16 were applied when sowing, with 120 kg ha^{-1} N (ammonium sulphate) and 50 kg ha^{-1} K_2O (potassium chloride) applied manually per plot as cover (stage V6 of the sorghum).

The sorghum was harvested for silage 105 days after sowing (DAS) (21 Feb 2014) in the first year of the experiment, and 124 DAS (7 Mar 2015) in the second year, when the grain in the panicle appeared to be at the farinaceous stage. During the interval between cutting in the first year and sowing in the second year, regrowth management of the sorghum and forage grasses took place, with subsequent desiccation for the no-till system.

When harvesting the plants in each treatment, the following attributes were evaluated in the forage sorghum: plant height (from the collar to the end of the panicle); basal stem diameter (determined by calliper at the second internode from the collar), measured in ten randomly chosen plants per plot; final stand (counting the total number of plants in the three central rows, three metres in length). Fresh matter production in the sorghum, grasses and pigeon pea was evaluated by collecting all the material found in 1 m² (3 replications/plot), which was cut 0.30 m from the ground and weighed on a digital balance; the sorghum was then separated into stem, leaves and panicle for the various parts to be quantified.

After weighing the fresh matter, sub-samples were removed and again weighed to determine the dry matter production of the sorghum, forage grasses and pigeon pea, as well as the various parts of the sorghum. For this, the material was placed in a forced air circulation oven at 65 ºC for 72 hours.

The results were subjected to analysis of variance, considering the treatments, the years, and the interaction between these factors as the sources of variation, with the interaction broken down or not depending on its significance by F-test. Tukey's test at 5% probability was used to compare the mean values employing the SISVAR software (FERREIRA, 2011).

RESULTS AND DISCUSSION

Table 1 shows the results for mean height, basal stem diameter and stand in the sorghum plants at the time of the first cut. Significance was found ($P<0.05$) between all the attributes under evaluation for the intercropped systems, the years, and their interaction.

In analysing the breakdown between years for each treatment, the greater plant height seen during the first year (Table 1) can be attributed to the smaller stand, and therefore, to less intraspecific competition, with more light intercepted by the leaves and a larger individual area for exploiting the soil. This was mainly due to the low rainfall that occurred immediately after sowing (Figure 1), together with the higher temperatures during the first year and a higher rate of photosynthesis.

However, Rabelo *et al*. (2012), studying sowing strategies and fertilisation with NPK in sorghum, found that plants grown at a population density of 12 plants per metre were taller, due to the intraspecific competition in the search for light increasing the length of the internodes and, consequently, of the plant. According to May *et al*. (2012a), competition for light is one of the modes of interference that most alters plant growth, as it limits the main source for energy absorption to the basic processes of recruiting elements and producing each substance involved in the growth of the plant.

In breaking down treatment interaction within each year (Table 2), the sorghum plants intercropped with marandu grass and pigeon pea (2.58 m), and as a single crop (2.28 m), presented the greatest heights during the first and second year respectively.

Studying the characteristics of four sorghum genotypes for silage production, Botelho *et al*. (2011) found heights of between 2.10 to 2.35 m, values close to those found in the present study. Chiesa *et al*. (2008) also obtained heights of 1.72, 2.16 and 2.52 m in the sorghum hybrids AG2005E, AG60298 and BR101 respectively.

Albuquerque *et al*. (2011), evaluating forage sorghum cultivars at three different spacings over two agricultural years under the climate conditions of the semi-arid region of Minas Gerais, where the first year was considered rainy (519 mm) and the second year dry (219 mm), found that, irrespective of the attributes under analysis, during the first agricultural year, plant height was greater compared to the second year, with a mean of 3.34 and 2.19 m respectively.

Benício *et al*. (2011) however, studied the efficiency of different cultivars of *M. maximum* intercropped with sorghum under sources of phosphorus and found that at the end of the first year the height of the sorghum was greater when grown together with massai grass, due to its smaller size (around 0.70 m) and, therefore, to the lower competition for light between the sorghum and the grass. In general, the intercropped systems with forage grasses tested here did not alter the growth of the sorghum plants, due to their high competitive ability, being able to achieve the same performance as under single cultivation, according to reports by Kluthcouski and Aidar (2003) with data similar to those found in this experiment.

Table 1 - Mean values, Tukey's test and P-value (Anova) for height, basal stem diameter and stand, in sorghum intercropped with marandu grass, mombasa grass and/or pigeon pea, under an Integrated Farming Production System in a low-altitude region of Cerrado, at the time of the first cut. Selvíria MS

Treatment (Trmt)	Height (m)	Diameter (cm)	Sorghum stand (plants ha^{-1})
Sorghum/Marandu/Pigeon Pea	2.33 a	1.9 ab	260.431 ab
Sorghum/Marandu	2.30 ab	2.1 a	257.245 ab
Sorghum/Mombasa/Pigeon Pea	2.10 b	1.8 ab	178.875 b
Sorghum/Mombasa	2.22 ab	1.8 ab	178.389 b
Sorghum/Pigeon Pea	2.30 ab	1.7 b	303.657 a
Single Sorghum	2.24 ab	2.0 ab	256.579 ab
CV (%)	5.6	6.1	22.3
Year (Y)			
2013/2014	2.34 a	1.7 b	199.225 b
2014/2015	2.15 b	2.1 a	279.167 a
Anova (P-value)			
Trmt	0.0291	0.0273	0.0068
Y	0.0001	0.0000	0.0001
Trmt x Y	0.0015	0.0003	0.0255

Mean values followed by the same letter in a column do not differ by Tukey's test at 5% significance ($P<0.05$) for treatment, or by F-test ($P<0.01$) for year

Table 2 - Mean values and Tukey's test in the breakdown of the Treatment x Year interaction for height and basal stem diameter, in sorghum intercropped with marandu grass, mombasa grass and/or pigeon pea, under an Integrated Farming Production System in a low-altitude region of Cerrado, at the time of the first cut. Selvíria MS

Treatment	Height (m)		Diameter (cm)	
	2013/2014	2014/2015	2013/2014	2014/2015
Sorghum/Marandu/Pigeon Pea	2.58 aA	2.05 aB	1.8 aA	2.1 abA
Sorghum/Marandu	2.46 abA	2.13 aB	1.9 aB	2.2 aA
Sorghum/Mombasa/Pigeon Pea	2.13 cA	2.08 aA	1.5 bB	2.2 aA
Sorghum/Mombasa	2.25 bcA	2.19 aA	1.7 abB	2.0 abA
Sorghum/Pigeon Pea	2.41 abA	2.19 aB	1.8 aA	1.8 bA
Single Sorghum	2.20 bcA	2.28 aA	1.8 aB	2.1 aA
MSD row	0.18		0.5	

Mean values followed by the same lowercase letter in a column and uppercase letter on a row do not differ by Tukey's test (P<0.05) or by F-test (P<0.01). MSD: minimum significant difference by Tukey's test

Plant height and stem diameter may be positively correlated with fresh and dry matter production, however they can also show a positive correlation with the percentage of stalks and subsequent lodging, characteristics that are undesirable for efficient forage production (ALBUQUERQUE *et al*., 2011; MAY *et al*., 2012b).

For stem diameter (Table 1), and from the breakdown of the interaction between treatments and years (Table 2), it was found that during the second year the sorghum plants presented the greatest diameters and also the largest stands. These results are similar to those obtained by Fernandes *et al*. (2014), who evaluated the interference of inter-row spacing and plant population on the production of saccarine sorghum for two sowing times, the first season and the off-season, and found a decrease of 1.2 mm in stem diameter from 80,000 plants ha^{-1}. These results corroborate those obtained by May *et al*. (2012b), who state that an increase in plant population per hectare can result in a reduction in stem diameter.

When evaluating the breakdown of the interaction between treatments for basal stem diameter (Table 2), it was found that sorghum with marandu grass (1.9 cm), and sorghum with mombasa grass and pigeon pea (2.2 cm) were the two cropping systems with the largest stem diameters in 2013/2014 and 2014/2015 respectively.

Table 1 also shows that for the final stand of the sorghum plants, sorghum intercropped with mombasa grass (178,389 plants ha^{-1}), and with mombasa grass and pigeon pea (178,875 plants ha^{-1}) were the two treatments giving the smallest stands. The small stand in these intercropped systems can be explained by the accelerated growth and tillering of the mombasa grass, which may have contributed to greater competition with the sorghum, thereby reducing the stand.

From the data shown in Table 3, with the breakdown of the interaction between treatments, it appears that during the first year of production the sorghum intercropped with mombasa grass, and with mombasa grass and pigeon pea, were the only treatments showing a significant difference (P<0.01), since the greater initial competition between the sorghum and the forage grass resulted in a reduction in the stand, aggravated by there being little rainfall shortly after sowing the intercrops (Figure 1). Whereas during the second year of evaluation, for the sorghum intercropped with mombasa grass, and with mombasa grass and pigeon pea, there was an increase of 137% in the number of sorghum plants, a fact attributed to the greater rainfall distribution during the second year of evaluation, as shown in Figure 1.

Despite the low sorghum stands when intercropped with mombasa grass, and with mombasa grass and pigeon pea, the values are greater than those recommended for forage sorghum, which is between 100 to 150 thousand plants per hectare, nevertheless, it is worth highlighting the need for larger plant populations in intercropped systems due to the effect of competition, when the aim is to produce forage for silage. However, it can be seen in Table 1 that the mombasa grass had a strong competitive effect on the sorghum, showing, under the evaluated conditions of low water availability, the low viability of this type of intercropped system when the aim is to achieve regrowth in the sorghum, since, due to competition with the forage grass after harvesting, there is a significant reduction in sorghum regrowth for the production of silage or grain.

Oliveira *et al*. (2005), evaluating the characteristics of sorghum cultivars under three doses of nitrogen, found a population ranging from 167 to 213 thousand plants per hectare. Von Pinho *et al*. (2006) evaluated the behaviour of maize cultivars compared to groups of sorghum cultivars

Table 3 - Mean values and Tukey's test in the breakdown of the Treatment x Year interaction, for plant stand in sorghum intercropped with marandu grass, mombasa grass and/or pigeon pea, under an Integrated Farming Production System in a low-altitude region of Cerrado, at the time of the first cut. Selvíria MS

Treatment	Sorghum stand (plants ha^{-1})	
	2013/2014	2014/2015
Sorghum/Marandu/Pigeon Pea	205,861 abB	315,000 aA
Sorghum/Marandu	240,741 aA	273,750 aA
Sorghum/Mombasa/ Pigeon Pea	104,000 bB	253,750 aA
Sorghum/Mombasa	108,027 bB	248,750 aA
Sorghum/ Pigeon Pea	264,815 aA	342,500 aA
Single Sorghum	271,907 aA	241,250 aA
MSD row	119,378	

Mean values followed by the same lowercase letter in a column and uppercase letter on a row do not differ by Tukey's test (P<0.05) or by F-test (P<0.01). MSD: minimum significant difference by Tukey's test

for silage production, and obtained a stand of 127 thousand plants for forage sorghum compared to grain sorghum (167 thousand) and dual-purpose sorghum (143 thousand).

The data referring to fresh matter production in the sorghum, forage grasses, and pigeon pea, and to total fresh matter production in the treatments under evaluation, are shown in Table 4, where it can be seen that the monocropped sorghum (45.3 t ha^{-1}) afforded the greatest amount of plant biomass, while the sorghum intercropped with mombasa grass (22.1 t ha^{-1}), and with mombasa grass and pigeon pea (23.6 t ha^{-1}) had the lowest productivity. However, when evaluating total fresh matter production, there was no effect between treatments.

For Rezende *et al*. (2011), there is controversy in the literature regarding data on fresh matter production in sorghum, as a large number of cultivars are studied

Table 4 - Mean values, Tukey's test and P-value (Anova) for fresh matter production in sorghum (FMPS), forage grass (FMPFG), and pigeon pea (FMPP), and total fresh matter production (FMPT), for treatments evaluated under an Integrated Farming Production System in a low-altitude region of Cerrado, at the time of the first cut. Selvíria MS

Treatment (Trmt)	FMPS	FMPFG	FMPP	FMPT
	Kg ha^{-1}			
Sorghum/Marandu/Pigeon Pea	39,803.7 ab	1,181.2 b	3,133.3	44,118.2
Sorghum/Marandu	35,981.3 b	1,162.5 b	-	37,143.8
Sorghum/Mombasa/Pigeon Pea	23,606.2 c	14,370.8 a	2,358.3	40,335.3
Sorghum/Mombasa	22,148.3 c	19,062.5 a	-	41,210.8
Sorghum/Pigeon Pea	38,191.7 ab	-	2,600.0	40,791.7
Single Sorghum	45,304.2 a	-	-	45,304.2
CV (%)	29.4	42.2	53.3	20.7
Year (Y)				
2013/2014	29,238.3 b	11,118.7 a	788.9 b	41,145.9 b
2014/2015	39,106.8 a	6,769.8 b	4,605.6 a	50,482.2 a
Anova (P-value)				
Trmt	0.0000	0.0002	0.5586^{ns}	0.2101^{ns}
Y	0.0032	0.0072	0.0001	0.0021
Trmt x Y	0.2406^{ns}	0.0079	0.2692^{ns}	0.3709^{ns}

Mean values followed by the same letter do not differ by Tukey's test at 5% significance (P<0.05) for treatment, or by F-test (P<0.01) for year (graniferous, forage and dual-purpose), generating values greater or smaller than those obtained in this experiment.

According to the data shown in this research, it can be seen that total fresh matter production was maximised (8,877.5 kg ha^{-1}) (Table 4), with sorghum dry matter during the second year of production maximised as a result. This increase in productivity can be explained by the better initial water supply (Figure 1), and the greater mean plant population (80 thousand plants ha^{-1}) in the 2014/2015 crop (Table 1), compared to the previous year. These data are lower than those found by Botelho *et al*. (2011), who evaluated the agronomic characteristics of monocropped sorghum genotypes for silage production, and obtained a production of 51,850 kg ha^{-1} at the time of the first cut in the Volumax cultivar sown at 12 seeds per metre.

Gomes *et al*. (2006), evaluating various sorghum genotypes, found the lowest (17,637 kg ha^{-1}) and highest (57,126 kg ha^{-1}) yield in the BRS 701 and IPA467-4-2 cultivars respectively. For the Volumax cultivar, the authors obtained a fresh matter production of 22,672 kg ha^{-1}, a value close to those found in this study for sorghum intercropped with mombasa grass and sorghum intercropped with mombasa grass and pigeon pea. Whereas Rabelo *et al*. (2012), evaluating sowing strategies and fertilisation with NPK in sorghum on the agronomic attributes of the crop, found a fresh matter production of 27,280 kg ha^{-1} at a spacing of 0.80 m between rows, which can be attributed to less intraspecific competition at this spacing.

At high plant densities, intraspecific competition in the sorghum was confirmed by Lopes *et al*. (2005), who found higher grain production per plant at the lowest density of 100 thousand plants ha^{-1}, compared to the highest density of 220 thousand plants ha^{-1} at the two spacings under study, 0.5 and 0.8 m. These same authors found that fresh matter production in the forage sorghum increased linearly as a function of fertilisation, with increments of 417 kg ha^{-1} being seen for each unit increase in NPK.

There was no significant difference (P>0.05) in fresh matter (Table 4) or total dry matter (Table 5) production per intercropped system between the treatments under evaluation; however, there was a significant effect (P<0.01) when comparing the DMPT for each year, with an increase in production of 21.0% in the second year compared to year one (Table 5).

According to Borghi *et al*. (2004), fertilising maize by area and plant, population density, and plant development, as a function of the system of soil management, generally, in the absence of adverse conditions, results in the formation of larger and consequently heavier ears due to less competition between

Table 5 - Dry matter production in sorghum (DMPS), forage grass (DMPFG), and pigeon pea (DMPP), and total dry matter production (DMPT), under an Integrated Farming Production System in a low-altitude region of Cerrado, at the time of the first cut. Selvíria MS

Treatment (Trmt)	DMPS	DMPFG	DMPP	DMPT
	Kg ha^{-1}			
Sorghum/Marandu/Pigeon Pea	16,123.7 a	415.1 b	1,031.1	17,569.9
Sorghum/Marandu	15,073.3 a	457.0 b	-	15,530.3
Sorghum/Mombasa/Pigeon Pea	8,793.0 b	4,979.4 a	817.2	14,589.6
Sorghum/Mombasa	8,415.3 b	6,062.6 a	-	14,477.9
Sorghum/Pigeon Pea	15,249.4 a	-	864.7	16,114.1
Single Sorghum	17,346.7 a	-	-	17,346.7
CV (%)	20.3	43.8	49.8	23.4
Year (Y)				
2013/2014	11,646.9 b	4,040.8 a	374.2 b	16,061.9 b
2014/2015	15,353.6 a	1,916.3 b	1,534.4 a	18,804.3 a
Anova (P-value)				
Trmt	0.0000	0.0000	0.5812^{ns}	0.2345^{ns}
Y	0.0055	0.0006	0.0001	0.0140
Trmt x Y	0.2257^{ns}	0.0009	0.2715^{ns}	0.3381^{ns}

Mean values followed by the same letter in a column do not differ by Tukey's test at 5% significance (P<0.05) for treatment, or by F-test (P<0.01) for year species and the better spatial arrangement of the plants together with proper fertilisation. This is due to the greater physiological capacity of the plants, a result of the greater water and nutrient absorption capacity of the intercropped systems; similar results to those of the sorghum intercrops evaluated here.

Over two years in Selvíria MS, Carvalho *et al.* (2004) obtained a mean value for dry matter weight of 2,478 kg ha^{-1} in pigeon pea sown in November and managed 60 days after emergence, albeit as a single crop. This was higher than the value found in this study (mean of 904.3 kg ha^{-1}) (Table 5), intercropped with sorghum, and with Mombasa and Marandu grass.

When developing a study to evaluate fresh and dry matter production in cover plants under three crop successions and two types of soil preparation in a typical dystrophic Red Latosol, Suzuki and Alves (2006) found that pigeon pea afforded the lowest dry matter production (6,465 kg ha^{-1}), a behaviour that is consistent with that seen by Almeida (2001). This author states that low dry matter production in the pigeon pea may be associated with its slow development, which enabled weeds to emerge and compete with the pigeon pea for water, light and nutrients. This observation is also valid for the conditions of the present experiment, where the intercropped systems have the same basis for competition as that provided by the weeds, not least because the grasses tested here have C4 metabolism, with more vigorous growth than the pigeon pea with C3 metabolism.

Based on the fresh matter of the sorghum, significant differences between the treatments under study were found regarding the percentage of stems and leaves, with no significant difference for the percentage of panicles (Table 6). The highest and lowest percentage of stems was 64.5 and 54.8% respectively, for single sorghum and sorghum intercropped with mombasa grass; however, taller sorghum hybrids may have a greater percentage of stems, which can compromise the nutritional quality of the silage produced from these hybrids (ZAGO, 1997).

The results of this research are close to those found by Botelho *et al.* (2011), who evaluated sorghum genotypes for silage production and found mean values for the percentage of stems ranging from 55.1 to 68.0%, while Oliveira *et al.* (2005) found percentages of 63.6 to 85.8% in sorghum hybrids in a typical clayey dystrophic Red Latosol, similar to that of the present study.

The percentage of leaves in the sorghum plants varied between 25.0 and 29.7% (Table 6), with the intercropped sorghum and mombasa grass having the highest percentage (29.7%). The lowest percentage

Table 6 - Mean values, Tukey's test and P-value (Anova) for the percentage of stem, leaf and panicle fractions in sorghum intercropped with marandu grass, mombasa grass and/or pigeon pea based on the fresh matter, under an Integrated Farming Production System in a low-altitude region of Cerrado, at the time of the first cut. Selvíria MS

Treatment (Trmt)	Stem	Leaves	Panicle
		%	
Sorghum/Marandu/Pigeon Pea	60.6 ab	27.2 ab	12.2
Sorghum/Marandu	63.5 a	25.0 b	11.5
Sorghum/Mombasa/Pigeon Pea	58.8 ab	29.5 ab	11.7
Sorghum/Mombasa	54.8 b	29.7 a	15.5
Sorghum/Pigeon Pea	62.0 ab	26.8 ab	11.1
Single Sorghum	64.5 a	25.6 b	9.9
CV (%)	6.6	14.3	19.8
Year (Y)			
1	59.3 b	26.9	13.7 a
2	62.1 a	27.7	10.2 b
Anova (P-value)			
Trmt	0.0114	0.0057	0.4230^{ns}
Y	0.0441	0.9097^{ns}	0.0008
Trmt x Y	0.2465^{ns}	0.4978^{ns}	0.1074^{ns}

Mean values followed by the same letter do not differ by Tukey's test at 5% significance (P<0.05) for treatment, or by F-test (P<0.01) for year of leaves was found in the sorghum intercropped with marandu grass (25.0%), and in the single sorghum (25.6%), showing no significant difference between each other.

When the percentage of leaves is analysed between years, no significant difference is seen. Gomes *et al*. (2006), evaluating sorghum genotypes (BR100, Volumax, SHS 500, MASSA 03, BRS 701, 0698005, AG 2005E, BRS 506, 0698007, BR601 and IPA467-4-2), determined a higher percentage of leaves (23.0%) in the Volumax cultivar, with a value below those shown in this research.

Among the various parts of the sorghum, the most important is the panicle, where the greatest nutritional value of the plant is concentrated, given the greater digestibility coefficient of the grain in relation to the stalk and leaves. For the sorghum genotypes BR100, Volumax, SHS 500, MASSA 03, BRS 701, 0698005, AG 2005E, BRS 506, 0698007, BR601 and IPA467-4-2, Gomes *et al*. (2006) found a mean CP content of 9.7 % in the panicle, a higher value than found in the leaves (6.3%) or stalk (1.7%).

The percentage of panicles found in the treatments varied from 9.9 to 12.2% (Table 6). Von Pinho *et al*. (2007) compared sorghum productivity as a function of sowing time, and obtained 17.7% of panicles in the forage genotype, a value higher than those found in this work. It is worth pointing out the greater percentage of panicles in the intercropped systems in relation to the single sorghum, even if not significant (P>0.05). In general, these percentages were higher for the cropping systems under evaluation compared to the values obtained by Chiesa *et al*. (2008), who evaluated the percentage of panicles in sorghum fresh matter, and found values of 5.0, 2.2 and 2.0% respectively, for the AG 2005E, AG 60298 and BR 101 genotypes.

CONCLUSIONS

1. Plant height and stem diameter in the sorghum, as well as stand, were influenced by the prevailing climate conditions during each agricultural year;
2. Fresh matter production in the sorghum was influenced by the cropping system, however, there was no difference in total fresh or dry matter production in the intercropped systems;
3. Sorghum intercropped with mombasa grass gave a higher percentage of panicles in the fresh matter, as well as a better ratio of plant components (stem, leaves and panicle).

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