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Yield of sorghum silage intercropped with pigeon pea and marandu grass in two spacings and chemical composition before and after ensiling

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Abstract

The aim of the present study was to evaluate yield of sorghum grown either solely (monoculture) or intercropped with *Urochloa brizantha* cv. Marandu and pigeon pea cv. BRS Mandarin in two spacings. The experiment was carried out in field condition and the experimental design was in a 2 x 4 factorial scheme with four replications. The treatments consisted of two sorghum spacings, combined with four forms of cultivation as follows: (T_1) sorghum as a monoculture (SOR); (T_2) sorghum intercropped with marandu grass (SMG); (T_3) sorghum intercropped with pigeon pea (SPP); and (T_4) sorghum intercropped with marandu grass and pigeon pea (SMP). The evaluated traits were: sorghum height, stem diameter of sorghum, number of sorghum leaves, and a ratio sorghum/pigeon pea /marandu grass. The data were submitted to the statistical program SISVAR, and averages compared by the Tukey test at 5% probability. The 0.45 m spacing between rows provided higher silage yield in relation to 0.90 m between sorghum rows. The highest silage yield was produced at 0.45 m spacing between rows for single sorghum and triple intercropped (T_4). The triple intercropped (sorghum + pigeon + marandu grass brachiaria) did not affect silage yield with the advantage of 10% of a legume in the final composition.

Keywords: *Cajanus cajan*; forage; legume; Sorghum bicolor; *Urochloa brizantha.*
Abbreviations: DM, dry matter.

Introduction

The vast areas of degraded pasture in Brazil have been promoting efforts to restore these areas and increase the yield (Sattler, 2018). It is estimated that more than 50% of pasture areas are degraded, which amounts to more than 80 million hectares. According to Oliveira et al. (2005) the recovery of these areas is a fundamental task in economic, technical and environmental terms.

The insertion of annual crops in pasture areas is an alternative for the recovery of these areas (Balbinot Junior et al., 2009). The use of legumes, especially soybean, can create several economic and environmental benefits, especially due to the synergy of cultivation with grasses (Franchin, et al., 2016). It is essential to consider the soil condition when cultivation of legume is important. Therefore, cultivation of annual crops for the first timer after pasture needs rustic species with potential of silage consortium and production would be timely. According to Rocha et al. (2003), the knowledge of the biological potential of the forage species is essential to establish adequate forage planning; thus, allowing a better relationship between yield and economics.

In addition, the maize-grass consortium for silage or to compose production systems is already well established, and several works already were developed (Freitas et al., 2005; Borghi and Crusciol, 2007, Pariz et al., 2008, Pariz et al. 2010; Bravin & Oliveira, 2014; Pariz et al., 2016). Recently, sorghum has also been studied in a consortium with grass and legumes (Calvo et al., 2010; Ribeiro et al., 2015, Costa et al., 2016), mainly due to the need to use more rustic species under unfavorable soil conditions or climate.

For establishment of intercropping (consortia), it is important to know how the adaptation of the plants will be, so that the conditions imposed allow each species to develop the physiological potential and express the ability to produce phytomass or grains. Sorghum, pigeon pea and brachiaria, are rustic species with potential to be cultivated as consortium and development under adverse conditions. When the sorghum is intercropped with pigeon pea there is a greater synchronism of growth between both species, which favors the balance in the phytomass composition (Calvo et al., 2010).

In regions with water deficit during the summer, forage planning is a success factor for the production system, mainly in the initial process of soil and pasture fertility recovery. One of the strategies that is being adopted for pasture recovery is integrated crop-livestock systems. In this context, at the beginning of the transition from pasture to crop, it is essential to use an annual crop that that allows the production of silage, in view of the reduction of pasture area. At the beginning of the pasture transition to integrated crop-livestock systems, fertility is low and the soil profile is under construction. This requires the use of a more rustic crop that tolerates high temperatures and water deficit.

The intercropping of grain crops with forages can be adopted to anticipate pasture establishment and improve soil cover for no-till. The maize and sorghum crops have been recommended in annual-pasture crop consortia, due to the greater capacity of competition with forage grasses in the initial stage of establishment (Vilela et al., 2011).

Among the annual crops that can be ensiled, sorghum has been extensively exploited for its greater resistance to summer water deficit and lower soil fertility requirement (Dias et al., 2001). According to Ribas (2010), sorghum is able to develop in poor soils and in places with low availability of water, which may pose greater risks to other crops. However, sorghum silage presents low nutritive value due to the higher fiber content (Oliveira, et al., 2010). However, it has the advantage of rusticity and lower cost of production (Santos et al., 2009).

The adaptability of sorghum to silage production is related to its size, which can vary from one to four meters in height (Diniz, 2010). When sorghum is cultivated in consortium with grass, there will be a good production of forage dry matter (Crusciol et al., 2009). In addition, sorghum has a good yield in sugar-rich stalks and good grain yield (Ribeiro Filho et al., 2008), an excellent and efficient energy source for ruminants despite its protein deficiency (Santos et al., 2009).

The consortium of forage plants is a technique that consists the practice of growing two or more crops in the same area to increase the yield and the quality of the product obtained with greater efficiency of use of the available resources.

The legume and grass species consortium (they are palatable and can feed the animals), brings great benefit to the production system, such as increased biomass production, biological nitrogen fixation and forage quality for animal feed (Tiritan et al., 2013). Thus, the hypothesis of this study is intercropping sorghum with legume and brachiaria to produce quality silage with higher volume per area.

The objective of the project was to evaluate the quality and yield of single sorghum and intercropped with *Urochloa brizantha* cv. Marandu; and also with pigeon pea cv. BRS Mandarim in two spacings.

Results and discussion

Silage production

Silage yield at 0.45 m spacing was higher for single sorghum treatments and for the triple consortium (Table 1). The mean of these two treatments was 93.0 t ha^{-1}. This value is 30% higher than the treatment with lower production of (64.0 t ha^{-1}). In the spacing of 0.90 m, the treatment of sorghum + marandu grass was the one that presented the highest production, with 61.7 tons ha^{-1}. In another treatment the average yield was 52.6 t ha^{-1} of fresh matter. The high yield of single sorghum silage in the 0.45m spacing was produced due to the lack of competition with brachiaria in the initial development phase.

In both spacings, the percentage of the production of marandu grass in the consortium with sorghum was not statistically different. It was only 0.70% higher than the average of the total marandu grass production and only 0.29% of the triple consortium. Silva et al. (2010) observed that sorghum and maize consortia with other species significantly outperformed their monoculture phytomass yield. Calvo et al. (2010) reported that there is a greater synchronism of growth between both species in the consortium of sorghum + guandu-dwarf, which favors the balance in the phytomass composition of the cover crop.

The pigeon pea in consortium with the sorghum had a DM production of 10%, while there was no difference between the spacings. In the triple consortium, DM production of pigeon pea and marandu grass were equal to 6%, both at 0.45 m spacing. However, in the spacing of 0.90 m, the percentage of DM of the pigeon pea was 9% and the marandu grass 13% (Fig 1).

Sorghum DM per hectare (Table 2) had no significant difference in single sorghum and triple consortium, being 48.40% and 45.40%, respectively, both at 0.45 m spacing, which were 1.36% higher than the average of the other treatments. This was only 0.80% higher compared to the general average.

The production of pigeon pea (Table 2) did not differ statistically between the spacings, nor between the treatments, and averaged 4.66%.

The DM production of the consortia differed only in the spacing of 0.90 m, in the consortium with marandu grass and in the consortium with pigeon pea, (9.7% and 7.8%, respectively), which were lower than the other treatments that had a production ranged of 11.5% to 13.8% (Table 2).

Calaça (2014), did not find any difference in DM production of forage sorghum BRS 655 neither in a single system nor in consortium with soybean and sorghum off-season.

The mean DM yield was 37.28 (t ha^{-1}) and the single sorghum (Table 2) had the lowest yield (27.71 ton ha^{-1}). The sorghum + marandu grass consortium + pigeon pea presented the highest yield (51.35 t ha^{-1}). In the sorghum + marandu grass consortium, the average yield of DM was 35.54 (t ha^{-1}), demonstrating that the consortium can increase DM production. In the triple consortium, sorghum contributed to 88% of DM, while pigeon pea only 8% (Table 2).

Costa et al. (2015), evaluated dry mass yield of maize and sorghum for silage (single crop, in a consortium with *Urochola brizantha* cv. Xaraés and *Panicum maximum* cv. Tanzania). They obtained a yield of 27.93 and 35.08 (t ha^{-1}) when sorghum was cultivated in consortium with Xaraés grass and Tanzania grass, respectively.

Rezende et al. (2001) evaluated the sorghum-soybean consortium and verified an advantage of 42.1% of total dry matter in consortium (intercropping systems) compared to monoculture of sorghum hybrids.

Biometric analysis

For the parameters plant height, leaf number, and stem diameter of sorghum (Table 2), there were no significant differences observed due to the variation of the spacing and the modality of the consortium.

Studies on influence of the spacing and the population of sorghum plants indicates that the plants grown in increased spacing have higher growth due to lower competition

Table 1. Production of silage (t ha^{-1}) in single sorghum system and in consortia with marandu grass and pigeon pea, in two spacing.

Treatments[1]	Silage prod (t ha^{-1}) 0.45 m[2]	Silage prod (t ha^{-1}) 0.90 m[2]
Sorghum single	96.23 aA	56.76 bAB
Sorghum + marandu-grass	64.00 aC	61.76 aA
Sorghum + Pigeon pea	80.10 aB	51.22 bB
Triple consortium[3]	90.22 aA	51.83 bB
		P < F
Spacing		< 0.01
Treatments		< 0.01
Spacing* Treatments		< 0.01
Plots		0.1421
Average overall		69.03

[1]Treatments with sorghum; [2]Spacings between rows (0.45 m and 0.90 m); [3]Triple consortium: Sorghum + Marandu grass + Pigeon pea. *Means followed by different lowercase letters in the row and upper case in the column differ from each other by the Tukey Test at 5% probability.

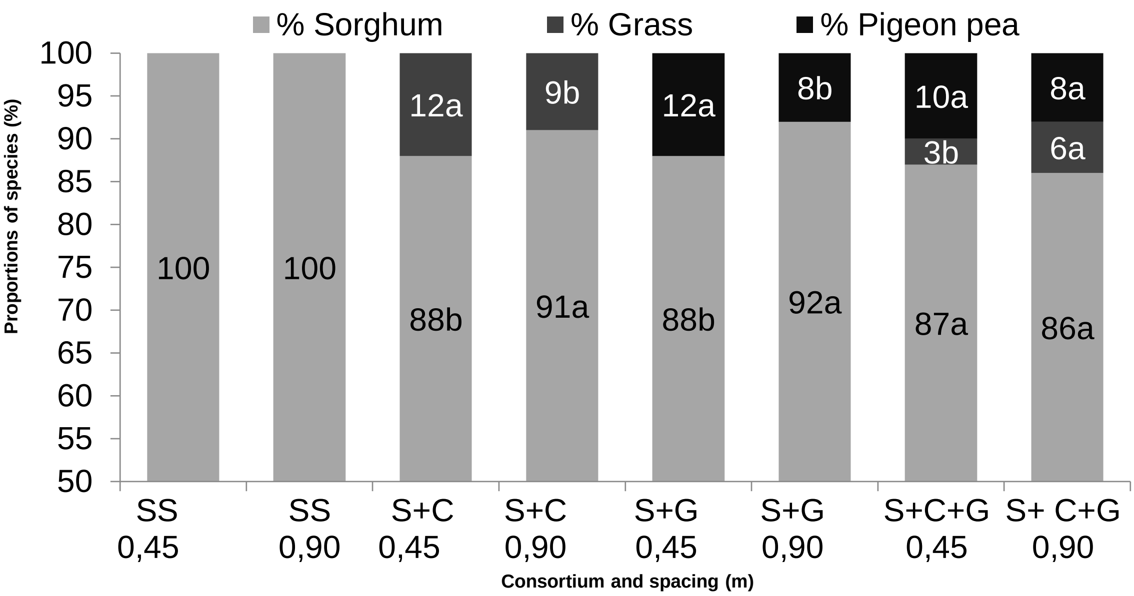

Fig 1. Percentage of sorghum dry mass (single and intercropped), marandu grass and pigeon pea at 0.45 m and 0.90 m spacing between sorghum lines. SS: Single sorghum with spacing of 0.45 m and spacing of 0.90 m; S + C: sorghum in a consortium with marandu grass; S + G: sorghum in consortium with pigeon pea; S + C + G: Sorghum in a consortium with marandu grass and pigeon pea.

Table 2. Yield of dry mass, height, number of leaves, stem diameter of single sorghum and intercropped with marandu grass and/or pigeon pea in two spacings.

Treatments	Spacing[1] (m)	DMS[2] (t ha^{-1})	DMT[3] (t ha^{-1})	Height (m)	Leaves (nº plant^{-1})	Diameter (mm)
Single Sorghum	0.45	48.40 Aa	48.40 aA	3.68 aA	15.23 aA	18.90 aA*
	0.90	27.71 bA	27.71 bA	3.82 aA	15.68 aA	19.93 aA
Sorghum + marandu-grass	0.45	37.69 aB	37.69 aB	3.19 aA	14.63 aA	19.80 aA
	0.90	33.39 aA	33.39 aA	3.57 aA	15.65 aA	19.20 aA
Sorghum + Pigeon pea	0.45	40.76 aB	40.76 aB	3.69 aA	15.53 aA	18.62 aA
	0.90	29.16 bA	29.16 bA	3.85 aA	15.30 aA	19.31 aA
Triple consorcium[2]	0.45	51.35 aA	51.35 aA	3.54 aA	14.60 aA	18.59 aA
	0.90	29.84 bA	29.84 bA	3.64 aA	15.23 aA	18.77 aA
				P < F		
Spacing		< 0.01		0.0027	0.1622	0.5278
Treatments		0.0281		0.0002	0.6171	0.6355
Spacing* Treatments		0.0004		0.3398	0.5923	0.6955
Plots		0.1398		0.6170	0.6104	0.6487
Average overall		37.28		3.62	15.22	19.14

[1]Spacing (0.45 m and 0.90 m); [2]DMS: Sorghum dry matter; [3]DMT: total dry matter (sorghum+grass+pigeon pea); [4]Height: height of sorghum (m); [5]Leaves: number of sorghum leaves (nº); [6]Diameter: sorghum stem diameter at cutting height (0.20 cm). Means followed by lowercase letters differ from one another for spacing and upper case for consortium, by Tukey's test at 5% probability.

between the plants and better spatial distribution of the plants (Fernandes et al. 2014)

According to Magalhães and Durães (2003), the number of leaves varies from 7 to 30. Possibly, the average result obtained from 15.2 leaves of sorghum in this experiment is believed to be related also to the genotype of the plants, which are sweet sorghum.

Fernandes et al. (2014) observed a negative linear relation between spacing and diameter of stalks/stem ($P < 0.05$) as a function of plant population. With the increase of 60,000 ha^{-1} plants to 80,000 ha^{-1}, there was a decrease of 1.21 mm in stem diameter. May et al. (2012), reported that increase in density of sorghum might result in reduction of diameter, positively correlating with lodging and breaking of plants.

In the present study, albeit differences were found in the silage production, but there was no statistical difference between the treatments influencing stem diameter of the sorghum. We observed difference of up to 1.4 mm between the means, with the lowest average of 18.5 mm in triple consortium and reduced spacing with the highest mean 19.9 of stalks diameter in the single sorghum (Table 2).

Material and methods

Plant material and growing conditions

The experiment was conducted at the Experimental Farm of Unoeste, located in the municipality of Presidente Bernardes-SP, in a Dystroferric Red Argissolo soil (Embrapa, 2006). The location of the experimental area is defined by the geographical coordinates: 22º 28 '25 "South Latitude and 51º 67' 88" West Longitude, with an average elevation of 430 meters and smooth undulating relief. The predominant climate in the region, according to the Köppen classification, is the Cwa type, with average annual temperatures around 25ºC and rainfall characterized by two distinct periods, one rainy from October to March and another with low rainfall from April to September. The average annual rainfall is 1,300 mm. The experimental period was conducted from December 2014 to May 2015.

Experimental design

The experimental design was a 2 x 4 factorial scheme, with four replications. The treatments consisted of two sorghum spacings (0.45 and 0.90 m), combined with four forms of cultivation (T1 single sorghum, T2 sorghum intercropped with marandu grass, T3 sorghum consortium with pigeon pea and; T4 sorghum consortium (intercropped) with marandu grass + pigeon pea). The experimental units (bands) were composed of eight lines of sorghum for spacing 0.90 m and seven lines for the spacing 0.45 m, and the length of the bands was 100 m. For evaluation purpose, the two central lines were considered in each spacing.

Conduction of study

Sorghum and pigeon pea were sown simultaneously, with sowing mechanism of the main crop (sorghum) first and additional box for other seed (intercrop), which allowed simultaneous implantation of both crops. The sorghum sowing rate was seven seeds per meter for the 0.45 m spacing and ten seeds for the 0.90 m spacing. Next to the each line of sorghum a line of pigeon pea with 18 plants per meter was sown. Brachiaria was sown with a vincon seed former, before sowing sorghum and pigeon pea, in the amount of 10 kg ha^{-1} of seeds with a 70% cultural value.

The basic fertilization was done with the commercial formula 08-28-16 in the dosage of 350 kg ha^{-1}. For the cover fertilization, the formulation 30-00-20 was used in the dosage of 200 kg ha^{-1}. The fertilizer was applied at 25 days after emergence of the plants. The seeds used in the experiment were pre-treated with fungicides at a dose of 60 g 100 kg -1 of Carboxin and 60 g 100 kg^{-1} of Thiran. After 20 DAS, 5 mL ha^{-1} of Delmatrina was sprayed to control leaf stripper caterpillars, with a consumption of 240 L ha^{-1}.

Traits measured

One week before the cutting of the plants, counts were made at four random points of 5 m continuous of the sorghum lines to determine the final population. The final population of sorghum was six plants per meter for the spacing 0.45 m and 5 plants per meter for the spacing 0.90 m between rows.

Ten plants of sorghum were randomly cut in the useful area of the strips to estimate their productive potential, as well as to measure height, stem diameter, leaf number, and the results obtained were converted on average totals. Measurements of height of the sorghum were obtained using a graduated grid (mean distance in meters to about 15 cm of the soil, "cutting height", until the end of the panicles). In order to evaluate the sorghum stem diameter (mean distance in millimeters) we measured middle third of the stem using a digital caliper. The count of the sorghum leaves was done manually.

For the determination of the volume of produced grass at 0.45 m spacing, the grass laid between the two lines of the sorghum was collected in two meters length. For the spacing 0.90 m, all of the material between two lines of sorghum was collected by two meters in length. In both spaces, the area of grass sampled was 1.8 m^2, and the cut height was the same as sorghum (15 cm from the soil). The same procedure was used to sample the volume of pigeon pea. All the pigeon pea were cut in two rows, at the spacings of 0.45 m and 0.90 m, both collections in two meters in length, corresponding to the same square area.

The sorghum, pigeon pea and cut grass were separated to determine the mass ratio of each species.

All mechanically consorted plants were also harvested in the useful area of the strips, and the crushed material was deposited directly on the bulk carrier. As it passed through the strips, samples of approximately 10 kg for each replicate were randomly withdrawn from the bulk carrier to determine the dry matter.

Statistical analysis

The variables analyzed in each treatment were submitted to the Sisvar statistical program (Ferreira, 2011), and the means were compared by the Tukey test at 5% probability.

Conclusions

The 0.45 m spacing provided higher silage yield in relation to 0.90 m between the sorghum lines. The highest silage production occurred in the 0.45 m spacing for single sorghum and triple consortium. The triple consortium (sorghum + pigeon pea + brachiaria) did not affect the yield of the silage with the advantage of the presence of 10% of a legume in the final composition.

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