Revista Ciência Agronômica
ISSN: 0045-6888
ISSN: 1806-6690
Universidade Federal do Ceará

Nakao, Allan Hisashi; Andreotti, Marcelo; Soares, Deyvison de Asevedo; Modesto, Viviane Cristina; Dickmann, Lourdes

Intercropping Urochloa brizantha and sorghum inoculated with Azospirillum brasilense for silage1

Revista Ciência Agronômica, vol. 49, no. 3, July-September, 2018, pp. 501-511
Universidade Federal do Ceará

DOI: 10.5935/1806-6690.20180057

Revista Ciência Agronômica, v. 49, n. 3, p. 501-511, jul-set, 2018
Centro de Ciências Agrárias - Universidade Federal do Ceará, Fortaleza, CE
www.ccarevista.ufc.br

Scientific Article
ISSN 1806-6690

Intercropping *Urochloa brizantha* and sorghum inoculated with *Azospirillum brasilense* for silage[1]

Consorciação de *Urochloa brizantha* com sorgos inoculados com *Azospirillum brasilense* para ensilagem

Allan Hisashi Nakao[2]*, Marcelo Andreotti[3], Deyvison de Asevedo Soares[2], Viviane Cristina Modesto[2] and Lourdes Dickmann[2]

ABSTRACT - Livestock performance in the Brazilian Cerrado has been limited by the low availability of good quality fodder, especially during periods of low rainfall. The aim of this study was to evaluate growth and dry matter production in two cultivars of sorghum, inoculated or not with diazotrophic bacteria, and as a monocrop or intercropped with palisade grass under a system of crop-livestock integration. The experiments were carried out in the field in the Cerrado region during the autumn-winter period of 2015 and 2016, on the experimental farm of the Faculty of Engineering at Ilha Solteira, UNESP, in Selvíria, in the State of Mato Groso do Sul, Brazil (MS). A randomised complete block experimental design was used in a 2 x 2 x 2 factorial scheme with four replications. The treatments corresponded to two agricultural years (2015 and 2016); the cultivation of dual-purpose grain sorghum, alone or intercropped with palisade grass; with or without inoculation of the sorghum seeds with the bacterium *Azospirillum brasilense*. The dry matter production of the plant components and plant growth were evaluated for the preparation of silage. Inoculation of sorghum seeds with the bacterium *Azospirillum brasilense* increases the production of plant dry matter for silage, irrespective of the cultivar or intercrop. Dual-purpose grain sorghum intercropped with palisade grass is a viable agronomic system for producing plant matter for silage during the autumn season.

Key words: Diazotrophic bacteria. Dry weight. *Sorghum bicolor* (L.) Moench. Palisade grass.

RESUMO - O desempenho da pecuária no Cerrado brasileiro tem sido limitado pela baixa disponibilidade de forragens de satisfatória qualidade, principalmente nos períodos de baixa precipitação pluvial. Objetivou-se avaliar o crescimento e a produtividade de massa seca de duas cultivares de sorgos inoculadas ou não com bactérias diazotróficas, exclusivamente ou em consórcio com capim-paiaguás, sob sistema de integração lavoura-pecuária, no período de outono-inverno, em região de Cerrado por dois anos agrícolas. Os experimentos foram realizados a campo, nos anos de 2015 e 2016, na fazenda experimental da Faculdade de Engenharia de Ilha Solteira, Unesp, em Selvíria-MS. O delineamento utilizado foi o de blocos casualizados, em esquema fatorial 2 x 2 x 2, com quatro repetições. Os tratamentos corresponderam: a dois anos agrícolas (2015 e 2016); cultivo de sorgo granífero e de dupla aptidão solteiros ou em consórcio com o capim-paiaguás, com ou sem a inoculação das sementes de sorgos com a bactéria *Azospirillum brasilense*. Avaliou-se a produtividade de massa seca dos componentes vegetais e o crescimento das plantas para confecção de silagem. A inoculação de sementes de sorgos com a bactéria *Azospirillum brasilense* aumenta a produção de massa seca vegetal para ensilagem, independentemente da cultivar ou consórcio com capim. A consorciação do sorgo granífero e dupla aptidão com o capim-paiaguás é um sistema viável do ponto de vista agronômico para produção de massa vegetal para ensilagem em cultivo outonal.

Palavras-chave: Bactérias diazotróficas. Massa seca. *Sorghum bicolor* (L.) Moench. Capim-paiaguás.

DOI: 10.5935/1806-6690.20180057
*Author for correspondence
Received for publication on 19/05/2017; approved on 20/10/2017
[1]Parte da Tese de Doutorado financiada pela Coordenação de Aperfeiçoamento de Pessoal de Nível Superior/CAPES
[2]Pós-Graduação em Sistema de Produção do Departamento de Fitossanidade, Engenharia Rural e Solos, Universidade Estadual Paulista "Júlio de Mesquita Filho", Ilha Solteira-SP, Brasil, allanhisashinakao@gmail.com, deyvison_a.soares@hotmail.com, vivianemodesto@hotmail.com, lourdesdickmann@hotmail.com
[3]Departamento de Fitossanidade, Engenharia Rural e Solos, Universidade Estadual Paulista "Júlio de Mesquita Filho", Ilha Solteira-SP, Brasil, dreotti@agr.feis.unesp.br

INTRODUCTION

When intercropping two grasses under a system of crop-livestock integration, the forage has the function of providing feed for the livestock from the end of the summer until the beginning of spring, and later of forming straw for the cultivation of the grain-producing crop. Such a system is one alternative in the search for new techniques that aim to reduce the costs of developing and reforming pasture, where there have been several studies into rotating annual crops with pasture and consolidating them into a system of crop-livestock integration (CLI) (BRAZ; MION; GAMEIRO, 2012).

Under the CLI system in areas of the cerrado, sorghum has been cultivated intercropped with species of the genus *Urochloa*, with positive results for dry matter and/or grain production (SILVA *et al*., 2013). *Urochloa brizantha* 'BRS Paiaguás', is seen as newly launched genetic material, possibly having significant advantages, such as greater adaptability under a crop-livestock integration system. However, the inconsistency of the results obtained in different regions of the country is evidence of the importance of conducting regionalised research, seeking to improve the efficiency of these productive systems, not only for the summer harvest, but especially for the autumn season. Another necessary area of research into intercropped sorghum is that the plants are of different heights and have different protein values; grain sorghum is smaller, and therefore in less competition with the intercropped forage. In addition, the larger quantity of grain results in higher concentrations of final protein in the silage when compared to dual-purpose sorghum or to forages of greater height; these probably have a greater competitive effect on the intercropped forage, albeit with less grain.

Due to the growing search for new technologies that aim for sustainability in agricultural production systems, several authors (COSTA *et al*., 2014; PARIZ *et al*., 2010) have presented intercropping with grain producing grasses as an alternative way of increasing forage production, offering the economy of pasture reform and the residual use of the nitrogen fertiliser applied to the main crop. Another alternative for saving nitrogen (N) is the commercial use of diazotrophic bacteria, also commonly classified as plant-growth promoting bacteria (PGPB) which, in addition to contributing to the biological fixation of atmospheric N_2 under the CLI system, can promote greater root growth, with better exploitation of the soil layers and a larger surface for water and nutrient absorption.

However, results of the interaction of diazotrophic bacteria with the CLI system in terms of agronomic potential, N_2 fixation or the promotion of plant growth are still scarce in the literature. Based on the above, the aim was to evaluate growth and dry matter production in both grain sorghum and dual-purpose sorghum, whether alone or intercropped with palisade grass and inoculated or not with *Azospirillum brasilense*, in the autumn season in the Brazilian Cerrado.

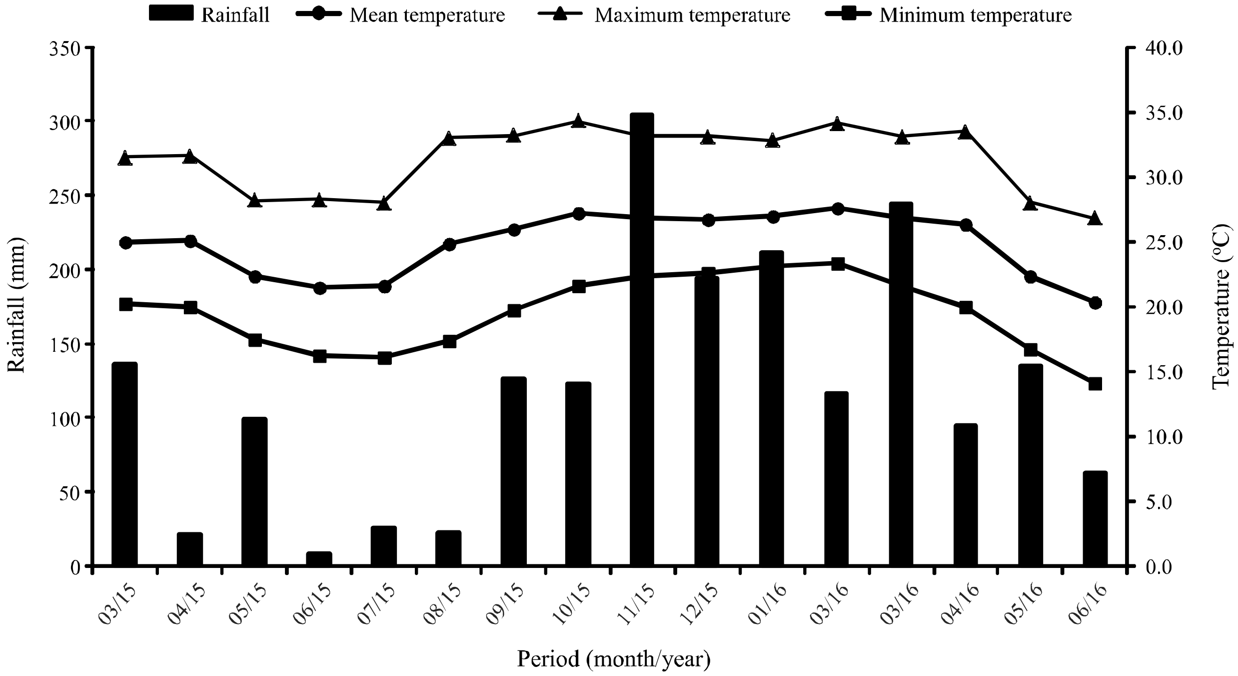
MATERIAL AND METHODS

The experiment was carried out on the Teaching, Research and Extension Farm of the Faculty of Engineering at UNESP, Ilha Solteira, located in the district of Selvíria, in the State of Mato Grosso do Sul (20º20'05" S and 51° 24'26" W, at an approximate altitude of 335 m). The annual average rainfall is 1370 mm, with an annual average temperature of 23.5 ºC and average relative humidity of 64.8%. Figure 1 shows data for rainfall, and maximum, mean and minimum temperature during the experiment. According to the Köppen classification, the climate in the region is type Aw, characterised as tropical humid with a rainy season in the summer and dry season during the winter. The soil of the experimental area, according to the Brazilian System of Soil Classification (EMBRAPA, 2013), is a typic clayey Dystrophic Red Latosol.

Before setting up the experiments, 20 soil samples were collected at a depth of 0.0-0.10 and 0.10-0.20 m, and a chemical analysis carried out to determine fertility, as per the methodology proposed by Raij *et al*. (2001). This revealed the following values for the chemical attributes at 0.0-0.10 m: pH ($CaCl_2$) = 5.4; 16.0 mg dm^{-3} P; 1.6, 27.0, 19.0, 28.0, 47.6 and 75.6 mmol$_c$ dm^{-3} K, Ca, Mg, H+Al, SB and CEC respectively; 24.0 g dm^{-3} organic matter and base saturation (V%) = 63.0. At 0.10-0.20 m, the values were: pH ($CaCl_2$) = 5.5; 17.0 mg dm^{-3} P; 1.2, 25.0, 16.0, 28.0, 42.2 and 70.2 mmol$_c$ dm^{-3} K, Ca, Mg, H + Al, SB and CEC,respectively; 20.0 g dm^{-3} organic matter and base saturation (V%) = 60.0.

A randomised complete block statistical design was used, in a 2 x 2 x 2 factorial scheme with four replications, the treatments comprising two years of cultivation (2015 and 2016), either as a monocrop (single) or intercropped with palisade grass, with or without inoculation of the sorghum seeds with the bacterium *Azospirillum brasilense*. The experimental area is part of two long-term experiments, the systems of crop-livestock integration being installed on 17 March 2015 in the first year and 6 April 2016 in the second, with two cultivars of sorghum ('Ranchero' and the dual-purpose cultivar 'A9902'). The seeds of the grain sorghum and dual-purpose sorghum were inoculated in the shade with the liquid inoculant moments before sowing, in both years.

Figure 1 - Rainfall and temperature obtained from the weather station on the Teaching, Research and Extension Farm of the Faculty of Engineering at UNESP, in the district of Selvíria, Mato Grosso do Sul, from March 2015 to June 2016



The cultivars were not compared as they have different genetic characteristics.

Before sowing the sorghum and the grass, the weeds in the area were desiccated with the herbicides Glyphosate (1440 g ha^{-1} a.i.) and Carfentrazone (20 g ha^{-1} a.i.). Sowing was carried out 10 days after applying the desiccants, on 17 March 2015 in the first year and 6 April 2016 in the second, the sorghum was sown by a no-tillage bar-type seeder-fertiliser, at a depth of approximately 0.03 m, spacing of 0.45 m and density of 10 sorghum seeds m^{-1}. For the intercropping set up when sowing the sorghums, the grass seed was sown between the rows of crops, at a spacing of 0.45 m using 10 kg seeds ha^{-1} with a CV of 60% of the *Urochloa brizantha* 'BRS Paiaguás'. The grass was sown mechanically with a no-tillage disc-type seeder-fertiliser at a depth of 0.06 m, in order to delay the emergence of the grass in relation to the grain-producing crop, and to reduce the probable competition between the species during the initial development period of the sorghum crop.

When sowing the sorghum cultivars, 12 kg ha^{-1} N, 90 kg ha^{-1} P_2O_5 and 30 kg ha^{-1} K_2O were applied as fertiliser in both years, as per the recommendations of Cantarella, Raij and Camargo (1997). The cover fertiliser for both cultivars and in both experimental years was applied mechanically 30 days after emergence of the crops, using 90 kg ha^{-1} N with ammonium sulphate as the source. The diazotrophic bacteria were supplied by the AZO Total inoculant at a dose of 100 mL/25 kg seeds (strains AbV5 and AbV6, with 2 x 10^8 viable cells mL^{-1}).

One day before harvesting the plants for silage production (70% DM), on 10 June 2015 in the first year and 12 July 2016 in the second, they were manually cut to a height of 0.25 m (both the sorghum and grass). The species were separated to determine the mean values for plant height of the grain sorghum (PHG) and the dual-purpose sorghum (PHDP), the basal stem diameter (BDG and BDDP) and the final stand (FSG and FSDP), as well as the dry matter production of the species, determined in two random samples per plot, using a 1 m^2 metal frame.

The stem fractions (DMSG and DMSDP), leaf fractions (DMLG and DMLDP) and panicles (DMPG and DMPDP) of the sorghum crops were separated with the aid of pruning shears, while for the palisade grass, all the above-ground parts were considered. The fractions were then weighed and placed in a forced ventilation oven at 65 ºC for 72 hours to determine the amount of each fraction, which together gave the total dry matter production of the sorghum plants (DMTG and DMTDP), and/or grass (DMGG and DMGDP) and sorghum + forages (PDMTG and PDMTDP).

After the regrowth of the sorghums and grasses in first year, the area was desiccated with Glyphosate herbicide (1.44 kg ha^{-1} active ingredient [a.i.]) and after ten days, the area was managed by a horizontal plant-residue grinder, aiming at continuity of the no-tillage system.

The results were submitted to analysis of variance by F-test and the mean values compared by Tukey's test at 5% probability using the SISVAR® statistical software (FERREIRA, 2011).

RESULTS AND DISCUSSION

There was greater plant height (PHG) in the grain sorghum (Table 1) during the first year of cultivation, possibly related to the higher productivity of the forage (DMGG) in the same year (Table 3) with consequent etiolation of the plants. This can occur because in large populations, plants tend to grow faster in order to avoid shading, which can affect other plant organs, such as stem diameter and leaf area (TAIZ; ZEIGER, 2004). In addition, the competition for space can result in reduced water and nutrient availability to the plants. This demonstrates the importance of a knowledge of forage species and of plant density under an intercropped system.

For the basal stem diameter (BDG), the years had no influence on the results. However, due to the competition in the intercrop with palisade grass, the grain sorghum plants had a smaller BDG than the monocrop. Mateus *et al*. (2011), working with two grasses (Mombasa and Marandu), intercropped with grain sorghum and as monocrops, found that the intercrop, independent of the species, resulted in a larger basal stem diameter than the monocrop, but only when grown under greater water availability. It is worth noting that the values for this attribute can increase the capacity to resist lodging and provide greater translocation of water and nutrients. Furthermore, the greater basal stem diameter is associated with the capacity of the plant for storing photoassimilates, resulting directly in grain filling (KAPPES *et al*., 2011). For the final stand of the plants, there was no significant difference from the treatments or initial adjustment of the stand.

Table 1 - Plant height (PHG), mean basal stem diameter (BDG) and final stand (FSG) in grain sorghum, for year of cultivation, alone or intercropped with palisade grass, and with or without *Azospirillum brasilense*

Treatment	PHG	BDG	FSG
	------------------------------ (cm)	--------------------------------	($pl\ ha^{-1}$)
Year			
1st Year	139.3 a	1.69	154.907
2nd Year	127.9 b	1.66	143.287
Grass			
With	133.5	1.61 b	145.555
Without	133.7	1.74 a	152.638
Inoculation			
With	134.7	1.70	147.685
Without	132.5	1.65	150.509
F-test			
Year (Y)	46.67**	0.46^{ns}	1.86^{ns}
Grass (G)	0.01^{ns}	8.01**	0.69^{ns}
Inoculation (I)	1.67^{ns}	0.87^{ns}	0.11^{ns}
Y x G	0.73^{ns}	0.42^{ns}	0.04^{ns}
Y x I	1.52^{ns}	1.87^{ns}	0.14^{ns}
C x I	2.53^{ns}	0.17^{ns}	1.10^{ns}
Y x G x I	3.91^{ns}	0.73^{ns}	0.20^{ns}
MSD	3.49	0.10	17.711
CV (%)	3.56	8.22	16.16

Mean values followed by the same letter in a column do not differ by Tukey's test at 5% probability. ** and *: significant at 1 e 5% respectively. ^{ns}: not significant

Table 2 - Dry matter production and percentage (%) of the leaf, stem and panicle fractions in grain sorghum (DMLG, DMSG and DMPG), for year of cultivation, alone or intercropped with palisade grass, and with or without *Azospirillum brasilense*

Treatment	DMLG	DMSG	DMPG
	----------	$t\ ha^{-1}$	----------
Year			
1st Year	1.94 (18.9%) b	3.74 (36.5%) b	4.57 (44.6%)
2nd Year	2.31 (16.5%) a	7.15 (51.3%) a	4.49 (32.2%)
Grass			
With	2.05 (17.7%)	4.98 (42.9%)	4.58 (39.4%)
Without	2.19 (17.4%)	5.91 (47.0%)	4.48 (35.6%)
Inoculation			
With	2.44 (18.4%) a	5.96 (44.9%) a	4.88 (36.7%)
Without	1.80 (16.5%) b	4.93 (45.2%) b	4.17 (38.3%)
F-test			
Year (Y)	5.19*	51.96**	0.05^{ns}
Grass (G)	0.83^{ns}	3.84^{ns}	0.08^{ns}
Inoculation (I)	15.33**	4.69*	3.50^{ns}
Y x G	0.01^{ns}	0.93^{ns}	0.41^{ns}
Y x I	0.01^{ns}	0.01^{ns}	0.02^{ns}
C x I	0.22^{ns}	1.23^{ns}	0.68^{ns}
Y x G x I	2.12^{ns}	0.53^{ns}	2.00^{ns}
MSD	0.33	0.98	0.78
CV (%)	21.53	24.57	23.63

Mean values followed by the same letter in a column do not differ by Tukey's test at 5% probability. ** and *: significant at 1 e 5% respectively. ^{ns}: not significant

In general, dry matter from the grain sorghum differed significantly ($p<0.05$) during the two agricultural years (Table 2). It can be seen that the highest values for these attributes (DMLG and DMSG) were obtained during the second year of the experiment. This fact may be related to the quantity of straw remaining after the regrowth of the sorghum of the previous year and to the climate conditions, with an increase in temperature and rainfall during the experimental period (Figure 1) resulting in better plant development. However, when evaluating the percentage participation of the sorghum fractions in the first year, the panicle had the greatest proportion, affording better feed composition due to the presence of the grain, whereas in the second year the stem had the highest percentage, with the greater amount of fibre resulting in a lower crude protein content in the dry matter for silage. According to Flaresso, Gross and Almeida (2000), the panicle is the most important component of feed quality in sorghum, as it results in high-energy silage.

In relation to the intercrop with the palisade grass, the dry matter weight of the sorghum fractions was similar, even with the competition between the intercropped plants. This agrees with the results of Crusciol *et al*. (2011), where there was no difference in grain production in sorghum mixed with marandu grass compared to the monocrop. According to Kluthcouski and Aidar (2003), grain sorghum shows great competitive power, and is able to be sown simultaneously with forage grasses. One hypothesis may be the release of allelopathic compounds by the grain sorghum influencing the development of the forage plants.

The DMLG, DMSG, DMTG and consequently the PDMTG (Tables 2 and 3), displayed higher productivity when inoculated with the bacterium. The influence of inoculating with *A. brasilense* has been reported by other authors, such as Nakao *et al*. (2014), who worked with foliar inoculation in a sorghum crop and obtained gains in stem, leaf and panicle dry weight. According to Dobbelaere *et al*. (2001), these bacteria have the function of biologically fixing atmospheric nitrogen and/or promoting growth mechanisms, which maximise plant ability to absorb and assimilate soil nutrients, and increase productivity.

Table 3 - Total dry matter (DMTG) production in grain sorghum plants, dry matter production (DMGG) in the forages and total dry matter production (PDMTG) of the pre-silage plant matter (grain sorghum + forages), for year of cultivation, alone or intercropped with palisade grass, and with or without *Azospirillum brasilense*

Treatment	DMTG	DMGG	PDMTG
	------ t ha^{-1} ------		
Year			
1st Year	10.26 b	1.21 a	11.47 b
2nd Year	13.95 a	0.46 b	14.41 a
Grass			
With	11.62	-	13.29
Without	12.59	-	12.59
Inoculation			
With	13.29 a	0.77	14.06 a
Without	10.92 b	0.90	11.82 b
F-test			
Year (Y)	22.31**	64.91**	14.78**
Grass (G)	1.55^{ns}	-	0.85^{ns}
Inoculation (I)	9.20**	2.06^{ns}	8.59**
Y x G	0.06^{ns}	-	0.51^{ns}
Y x I	0.01^{ns}	1.14^{ns}	0.01^{ns}
C x I	1.65^{ns}	2.06^{ns}	2.19^{ns}
Y x G x I	0.11^{ns}	1.14^{ns}	0.22^{ns}
MSD	1.62	0.19	1.59
CV (%)	18.24	31.08	16.71

Mean values followed by the same letter in a column do not differ by Tukey's test at 5% probability. ** and *: significant at 1 e 5% respectively. ^{ns}: not significant

The palisade grass (DMGG) developed more during the first year of cultivation because of the smaller amount of sorghum leaves causing less shading and competition between the species (Tables 2 and 3). Due to the high dry matter production obtained by the grain sorghum in the second year (2016), it was found that the total dry matter (grain sorghum + forages) was greater than in the first year by 2.9 t ha^{-1}, even with superior results for the grass in the first year.

In the first year (Table 4), there was greater growth in the height of the dual-purpose sorghum (PHDP) compared to the second year, which was also seen in the grain sorghum (Table 1) due to the effect of the larger population and probable plant etiolation. It was found that the first year was superior to the second for plant stand, where the greater deposition of straw on the ground, after management of the regrowth of the sorghum and grasses from the intercrops planted the previous agricultural year, could have interfered in seed germination in the second year. To reduce this effect in maize, Pariz *et al*. (2011) used a plant-residue grinder after chemical desiccation to manage the grasses, which was also done in the present study. However, sorghum may also have an allelopathic effect on the germination and growth of plants in succession under its straw, releasing allelochemicals during decomposition (PEIXOTO; SOUZA, 2002).

The intercrop with the palisade grass resulted in a smaller mean basal stalk diameter (BDDP) (Table 4). This may be associated with competition for growth factors during the intercrop. These results demonstrate the behaviour of dual-purpose sorghum when intercropped with grasses of the genus *Urochloa*, where in the autumn season, due to the greater water limitation, there is more competition between the intercropped plants. There was no effect from the inoculation on the mean basal stem diameter (BDDP).

An interaction was seen between the years of cultivation and inoculation with *Azospirillum brasilense* for PHDP (Table 4). In the breakdown of the interaction

Table 4 - Plant height (PHDP), mean basal stalk diameter (BDDP) and final plant stand (FSDP) in dual-purpose sorghum, for year of cultivation, alone or intercropped with palisade grass, and with or without *Azospirillum brasilense*

Treatment	PHDP	BDDP	FSDP
	------------------------------ (cm)	------------------------------	(pl ha^{-1})
Year			
1st Year	210.38 a	1.36	169.722 a
2nd Year	192.17 b	1.41	148.148 b
Grass			
With	200.28	1.33 b	158.333
Without	202.26	1.45 a	159.537
Inoculation			
With	202.08	1.40	155.925
Without	200.47	1.38	166.944
F-test			
Year (Y)	186.79**	0.73^{ns}	8.10**
Grass (G)	2.21^{ns}	5.17*	0.02^{ns}
Inoculation (I)	1.45^{ns}	0.10^{ns}	3.47^{ns}
Y x G	3.85^{ns}	0.01^{ns}	0.42^{ns}
Y x I	21.88**	0.01^{ns}	0.02^{ns}
C x I	0.26^{ns}	1.78^{ns}	3.29^{ns}
Y x G x I	2.83^{ns}	0.06^{ns}	0.98^{ns}
MSD	2.77	0.10	15.755
CV (%)	1.87	10.55	13.48

Mean values followed by the same letter in a column do not differ by Tukey's test at 5% probability. ** and *: significant at 1 e 5% respectively. ^{ns}: not significant

(Table 5), it was found that during the first year there was greater growth of the inoculated plants, while in the second year, with greater water availability, there was no significant effect. When the PHDP was compared within the year of cultivation, there was an increase with inoculation in the first year, with a decrease in the second year.

Table 5 - Breakdown of the significant interactions between year and inoculation, for plant height in dual-purpose sorghum (PHDP), for year of cultivation, alone or intercropped with palisade grass, and with or without *Azospirillum brasilense*

Treatment	Inoculation	
	With	Without
PHDP		
1st Year	214.30 aA	206.46 aB
2nd Year	189.86 bA	194.48 bA

Mean values followed by different lowercase letters in a column and uppercase letters on a line differ by Tukey's test at 5% probability

Kappes *et al.* (2013), working with *Azospirillum brasilense* inoculation in maize seeds in the Cerrado at low altitude, found an increase in plant height. In addition, Longhini *et al*. (2016) reported a positive effect on plant height in maize inoculated with the bacteria, which resulted in a significant increase in production, in relation to the uninoculated seeds.

Stalk and panicle dry matter production in the sorghum during the second year were higher than during the first year (Table 6), demonstrating that the experimental conditions of the residue left over from the first year due to regrowth of the sorghum and grass, which later became straw, give positive results from the ground cover and nutrient recycling, especially when observing the total dry matter production of the dual-purpose sorghum, with an increase in total dry matter production before silage (Table 7). Also of importance is the higher rainfall during the second year (Figure 1), explaining this greater increase in dry matter production.

The decrease in leaf, shoot and panicle production in the intercropped sorghum (0.43, 1.71, 0.65 t ha^{-1} respectively) (Table 6), is a result of competition with the grass. For this reason, intercropping is a technology to be studied in different growing seasons, in order to gain information about the behaviour of the competing species, which is fundamental to achieving satisfactory productivity in the grain crop and when creating pasture, since competition between the crops can make cultivation unviable (KLUTHCOUSKI; YOKOYAMA, 2003). Such competition could be minimised by sowing the grass at greater depths, delaying emergence; a methodology that was put into practice in the present study, but without success.

The increases seen in the DMLDP and DMSDP of the inoculated plants (Table 6) may be associated with the production of hormones by the bacteria, which stimulate the density and length of the root hairs (OKON; LABANDERA-GONZALEZ, 1994), resulting in greater uptake of the water and nutrients available in the soil. These results agree with other published results, in which there are positive responses related to the sorghum plant in the presence of diazotrophic bacteria. Bergamaschi *et al*. (2007), studying the occurrence of bacteria in forage sorghum, found satisfactory results for nitrogen fixation and the *in vitro* production of indoleacetic acid.

It was found that the dual-purpose cultivar produces more stem than leaves and panicle, indicating a higher concentration of fibres in the silage, which can result in silage of low quality. These results are in contrast with those obtained by Avelino *et al*. (2011) who, studying hybrids of dual-purpose and forage sorghum, found that the dual-purpose sorghum produces more panicles than leaves and stem. This result leads to the conclusion that the A9902 hybrid, in order to express its greater capacity for panicle production, should be cultivated at larger spacings when intercropped with grasses. Regionalised experiments should also be carried out.

The total dry matter production (PDMTDP) before silage (dual-purpose sorghum + palisade grass) remained

Table 6 - Dry matter production and percentage (%) of the leaf, stem and panicle fractions in dual-purpose sorghum (DMLDP, DMSDP and DMPDP), for year of cultivation, alone or intercropped with palisade grass, and with or without *Azospirillum brasilense*

Treatment	DMLDP	DMSDP	DMPDP
	---------- t ha^{-1} ----------		
Year			
1st Year	2.17 (19.4%)	5.56 (49.8%) b	3.44 (30.8%) b
2nd Year	2.07 (16.0%)	6.47 (50.0%) a	4.39 (34.0%) a
Grass			
With	1.91 (17.9%) b	5.16 (48.4%) b	3.59 (33.7%) b
Without	2.34 (17.4%) a	6.87 (51.1%) a	4.24 (31.5%) a
Inoculation			
With	2.31 (18.1%) a	6.70 (52.5%) a	3.76 (29.4%)
Without	1.93 (17.1%) b	5.33 (47.0%) b	4.07 (35.9%)
F-test			
Year (Y)	1.00^{ns}	10.77**	15.47**
Grass (G)	17.67**	37.89**	7.23*
Inoculation (I)	14.33**	24.19**	1.61^{ns}
Y x G	0.95^{ns}	4.24^{ns}	2.81^{ns}
Y x I	0.09^{ns}	0.29^{ns}	1.07^{ns}
C x I	3.13^{ns}	0.38^{ns}	1.03^{ns}
Y x G x I	1.84^{ns}	1.75^{ns}	0.96^{ns}
MSD	0.21	0.57	0.50
CV (%)	13.55	13.06	17.54

Mean values followed by the same letter in a column do not differ by Tukey's test at 5% probability. ** and *: significant at 1 e 5% respectively. ^{ns}: not significant

similar during both years of cultivation, with a decrease in dry matter production seen in the intercrop (Table 7). This result is similar to that of the grain sorghum (Table 3).

In the second year of cultivation, production was higher due to the effect of the sorghum in the intercrop (Table 7) which, due to the larger amount of residual straw during the first year of cultivation, improved the soil structure, biological activity and availability of water and nutrients under the no-tillage system. This demonstrates the importance of carrying out studies of this nature over longer periods.

Due to the competitive effect, dual-purpose sorghum intercropped with palisade grass showed a decrease in PDMTDP of 1.28 t ha^{-1} (Table 7). This result may indicate that the row spacing of 0.45 m, the high plant population and even the genetics of the highest-growing cultivar have a significant effect on the behaviour of the intercropped species. However, in a study by Garcia *et al*. (2013), an intercrop of forages of the genera *Panicum* and *Urochloa* with maize did not result in any significant competitive effect for grain production, albeit in an irrigated area during the spring/ summer crop, and with the maize at a row spacing of 0.90 m. In addition, Costa *et al*., evaluating an intercrop of maize with two species of *Urochloa* (*Brizantha* and *ruziziensis*) under a no-tillage system, found no difference in shoot dry matter production in the crop.

Evaluating the agronomic aspects of sorghum genotypes, Botelho *et al*. (2010) found a DM production in 'Volumax' sorghum of 16.6 t ha^{-1}, 'Qualimax' of 14.3 t ha^{-1}, 'BRS 610' of 17.5 t ha^{-1} and 'AG 2005E 'of 13.7 t ha^{-1}, close to that of the dual-purpose 'AG 2005E'.

When inoculating with *Azospirillum brasilense*, the total dry matter production was 1.71 t ha^{-1} higher than the uninoculated production, demonstrating the importance of these diazotrophic bacteria. According to Dartora *et al*. (2013), the combination of strains of *A. brasilense* and *Herbaspirillum seropedicae* resulted in

Table 7 - Total dry matter production (DMTDP) in dual-purpose sorghum plants, dry matter production (DMGDP) in the forage species and total dry matter production (PDMTDP) of the pre-silage plant matter (dual-purpose sorghum + forages), for year of cultivation, alone or intercropped with palisade grass, and with or without *Azospirillum brasilense*

Treatment	DMTDP	DMGDP	PDMTDP
	t ha^{-1}		
Year			
1st year	11.18 b	0.84	12.02 b
2nd Year	12.95 a	0.67	13.62 a
Grass			
With	10.67 b	-	12.18 b
Without	13.46 a	-	13.46 a
Inoculation			
With	12.78 a	0.89 a	13.68 a
Without	11.34 b	0.62 b	11.97 b
F-test			
Year (Y)	16.77**	3.83^{ns}	14.43**
Grass (G)	41.83**	-	9.16**
Inoculation (I)	11.17**	9.53**	16.51**
Y x G	0.02^{ns}	3.83^{ns}	0.06^{ns}
Y x I	1.00^{ns}	6.07*	2.35^{ns}
C x I	0.15^{ns}	3.89^{ns}	1.08^{ns}
Y x G x I	2.95^{ns}	3.07^{ns}	1.52^{ns}
MSD	0.89	0.17	0.87
CV (%)	10.11	32.20	9.28

Mean values followed by the same letter in a column do not differ by Tukey's test at 5% probability. ** and *: significant at 1 e 5% respectively. ^{ns}: not significant

better development in maize, compared to the control, especially for shoot dry matter. It is worth noting the effect of inoculation with *Azospirillum* in experimental field data, in which Okon and Vanderleyden (1997) concluded that grasses, such as sorghum, maize and rice, respond to inoculation with gains in productivity through the biological fixation of nitrogen and growth promoters, increasing the absorption surface of the plant roots and consequently increasing the volume of exploited soil substrate, under the most varied conditions of soil and climate. According to Bashan, Holguin and De-Bashan (2004), the benefits provided by the bacteria can be attributed to the production of such substances as auxins, gibberilins and cytokinins, which increase dry matter productivity, as found in this research.

From the breakdown of the interaction, there were significant differences for DMGDP between the years of cultivation, with and without inoculation (Table 8), with increases in productivity associated with inoculation in the second year. The viability of inoculating the sorghum seeds with *Azospirillum brasilense* could be seen from the transfer of the bacterium to the intercropped grass even though it had not been inoculated, as it increases forage production (dual-purpose sorghum + palisade grass) during the off season, in the period of greatest shortage of animal feed or making straw for no-tillage systems.

Table 8 - Breakdown of the significant interactions between year and inoculation, for dry matter in dual-purpose sorghum (DMGDP), for year of cultivation, alone or intercropped with palisade grass, and with or without *Azospirillum brasilense*

Treatment	Inoculation	
	With	Without
	DMGDP	
1st Year	0.86 aA	0.81 aA
2nd Year	0.91 aA	0.43 bB

Mean values followed by different lowercase letters in a column and uppercase letters on a line differ by Tukey’s test at 5% probability

In general, the intercrop did not alter the final dry matter production of the grain sorghum, making sufficient quantities available for silage; in addition, the regrowth of the sorghum (Grain and Dual-Purpose) and palisade grass, allowed the formation of hay and the continuity of the no-tillage system for the summer crop in the Cerrado region. Furthermore, it is possible to reduce the cost of creating pasture, and to offer feed to cattle in the off-season, when the supply of forage is reduced.

CONCLUSIONS

1. Due to the residual effect of the treatments and the regrowth, total dry matter production in the second year of cultivation under rainfed conditions in the Cerrado was higher;
2. Intercropping grain sorghum with palisade grass during the autumn season does not change dry matter or grain productivity, however in dual-purpose sorghum, it reduces leaf, stem and panicle dry matter production because of the competitive effect;
3. The inoculation of grain sorghum and dual-purpose sorghum seeds with *Azospirillum brasilense*, resulted in greater development of both the sorghum and palisade grass in the intercrop, providing increases in the shoot dry matter of both plant species.

REFERENCES

AVELINO, P. M. *et al*. Características agronômicas e estruturais de híbridos de sorgo em função de diferentes densidades de plantio. **Revista Ciência Agronômica**, v. 42, n. 2, p. 534-541, 2011.

BASHAN, Y.; HOLGUIN, G.; DE-BASHAN, L. E. *Azospirillum*-plant relationship physiological, molecular, agricultural, and environmental advances (1997-2003). **Canadian Journal of Microbiology**, v. 50, n. 8, p. 521-577, 2004.

BERGAMASCHI, C. *et al*. Occurrence of diazotrophic bacteria associated with forage sorghum cultivars. **Ciência Rural**, v. 37, n. 3, p. 727-733, 2007.

BOTELHO, P. R. F. *et al*. Avaliação de genótipos de sorgo em primeiro corte e rebrota para produção de silagem. **Revista Brasileira de Milho e Sorgo**, v. 9, n. 3, p. 287-297, 2010.

BRAZ, F. P.; MION, T. D.; GAMEIRO, A. H. Análise socioeconômica comparativa de sistemas de integração lavoura-pecuária em propriedades rurais nas regiões Sul, Sudeste e Centro-Oeste do Brasil. **Informações Econômicas**, v. 42, n. 2, p. 69-80, 2012.

CANTARELLA, H.; RAIJ, B. VAN.; CAMARGO, C. E. O. Adubação de cereais. *In*: RAIJ, B. VAN. *et al*. (Ed.). **Recomendações de adubação e calagem para o Estado de São Paulo**. 2. ed. Campinas: Instituto Agronômico, 1997. p. 43-50. (Boletim Técnico, 100).

COSTA, N. R. *et al*. Adubação nitrogenada em capins do gênero *Urochloa* implantados em consórcio com a cultura do milho. **Revista Brasileira de Ciências Agrárias**, v. 9, n. 3, p. 376-383, 2014.

COSTA, N. R. *et al*. Adubação nitrogenada no consórcio de milho com duas espécies de braquiária em sistema plantio direto. **Pesquisa Agropecuária Brasileira**, v. 47, n. 8, p. 1038-1047, 2012.

CRUSCIOL, C. A. C. *et al*. Nutrição e produtividade de híbridos de sorgo granífero de ciclos contrastantes consorciados com capim-marandu. **Pesquisa Agropecuária Brasileira**, v. 46, n. 10, p. 1234-1240, 2011.

DARTORA, J. *et al*. Adubação nitrogenada associada à inoculação com *Azospirillum brasilense* e *Herbaspirillum seropedicae* na cultura do milho. **Revista Brasileira de Engenharia Agrícola Ambiental**, v. 17, p. 1023-1029, 2013.

DOBBELAERE, S. *et al*. Responses of agronomically important crops to inoculation with *Azospirillum*. **Australian Journal of Plant Physiology**, v. 28, n. 9, p. 871-879, 2001.

EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA. Centro Nacional de Pesquisa dos Solos. **Sistema brasileiro de classificação de solos**. 3. ed. Brasília: Embrapa-SPI, 2013. 353 p.

FERREIRA, D. F. Sisvar: a computer statistical analysis system. **Ciência e Agrotecnologia**, v. 35, n. 6, p. 1039-1042, 2011.

FLARESSO, J. A.; GROSS, C. D.; ALMEIDA, E. X. Cultivares de milho (*Zea mays* L.) e sorgo (*Sorghum bicolor* (L.) Moench.) para ensilagem no Alto Vale do Itajaí, Santa Catarina. **Revista Brasileira de Zootecnia**, v. 29, n. 6, p. 1608-1615, 2000.

GARCIA, C. M. P. *et al*. Desempenho agronômico da cultura do milho e espécies forrageiras em sistema de Integração Lavoura-Pecuária no Cerrado.**Ciência Rural**, v. 43, n. 4, p. 589-595, 2013.

KAPPES, C. *et al*. Desempenho de híbridos de milho em diferentes arranjos espaciais de plantas. **Bragantia**, v. 70, n. 2, p. 334-343, 2011.

KAPPES, C. *et al*. Inoculação de sementes com bactéria diazotrófica e aplicação de nitrogênio em cobertura e foliar em milho. **Semina: Ciências Agrárias**, v. 34, n. 2, p. 527-538, 2013.

KLUTHCOUSKI, J.; AIDAR, H. Implantação, condução e resultados obtidos com o sistema Santa Fé. *In*: KLUTHCOUSKI, J.; STONE, L. F.; AIDAR, H. (Ed.). **Integração lavoura-pecuária**. Santo Antônio de Goiás: Embrapa Arroz e Feijão, 2003. p. 407-441.

LONGHINI, V. Z. *et al*. Inoculation of diazotrophic bacteria and nitrogen fertilization in topdressing in irrigated corn. **Revista Caatinga**, v. 29, n. 29, p. 338-347, 2016.

MATEUS, G. P. *et al*. Adubação nitrogenada de sorgo granífero consorciado com capim em sistema de plantio direto. **Pesquisa Agropecuária Brasileira**, v. 46, n. 10, p. 1161-1169, 2011.

NAKAO, A. H. *et al*. Resposta do sorgo granífero à aplicação de diferentes doses e épocas de inoculante (*Azospirillum brasilense*) via foliar. **Enciclopédia Biosfera**, v. 10, n. 18, p. 2702-2714, 2014.

OKON, Y.; LABANDERA-GONZALEZ, C. Agronomic application of *Azospirillum*: an evaluation of 20 years worldwide field incubation. **Soil Biology and Biochemistry**, v. 26, n. 12, p. 1591-1601, 1994.

OKON, Y.; VANDERLEYDEN, J. Root-associated *Azospirillum* species can stimulate plants. **Applied and Environmental Microbiology**, v. 63, n. 7, p. 366-370, 1997.

PARIZ, C. M. *et al*. Massa seca e composição bromatológica de quatro espécies de braquiárias semeadas na linha ou a lanço, em consórcio com milho no sistema plantio direto na palha. **Acta Scientiarum. Animal Sciences**, v. 32, n. 2, p. 147-154, 2010.

PARIZ, C. M. *et al*. Yield chemical composition and chlorophyll relative content of Tanzania and Mombaça grasses irrigated and fertilized with nitrogen after corn intercropping. **Revista Brasileira de Zootecnia**, v. 40, n. 4, p. 728-738, 2011.

PEIXOTO, M. F.; SOUZA, I. F. Efeitos de doses de imazamox e densidades de sorgo (*Sorghum bicolor* (L.) Moench) em soja (*Glycine max* (L.) Merril) sob plantio direto. **Ciência e Agrotecnologia**, v. 26, n. 2, p. 252-258, 2002.

RAIJ, B. VAN. *et al*. Análise química para avaliação da fertilidade de solos tropicais. Campinas: **Instituto Agronômico**, 2001. 284 p.

SILVA, A. G. *et al*. Consórcio na entrelinha de sorgo com braquiária na safrinha para produção de grãos e forragem. **Semina: Ciências Agrárias**, v. 34, n. 6, p. 3475-3488, 2013. Suplemento 1.

TAIZ, L.; ZEIGER, E. **Fisiologia vegetal**. 3. ed. Porto Alegre: Armed, 2004. 710 p.