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# Seeding density of *Brachiaria ruziziensis* intercropped with grain sorghum and effects on soybean in succession

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**Sorghum is an alternative crop to produce grains in the off-season in Brazilian Cerrado and the intercropping with *Brachiaria* species enable to produce dry matter on the soil surface for a longer time. However, there is limited information on *Brachiaria ruziziensis* seed density to be applied to intercropping with sorghum without causing decreases in sorghum grain yield. The objective of the study was to evaluate the seeding density of *B. ruziziensis* in different intercropped systems with grain sorghum grown after soybean harvest, in off-season cultivation, to produce grains and the effects of straw on the agronomic performance of the soybean crop in succession to intercropping. This study was conducted in the field during the 2014 off-season in Rio Verde, Goiás. The experimental design was complete randomized blocks in a 3×5 factorial arranged with four replications corresponded to intercropping on rows, inter-rows and broadcast sowing with the densities of 2, 4, 6, 8 and 10 viable pure seeds m$^{-2}$ of *B. ruziziensis*. Monocultures of sorghum and these forage crop were also evaluated. The results demonstrated the absence of effects of intercropping systems and seeding density on the yield of sorghum grains and on the cultivation of soybean in succession. The intercropping was effective in producing straw on soil surface to Cerrado no-tillage system.**

**Key words:** *Brachiaria* species, *Glycine max,* straw, off-season crop, *Sorghum bicolor.*

## INTRODUCTION

Currently, the diversification and integrated systems of activities on farms has become an essential tool for the stability of agribusiness. Modern agriculture has prioritized agricultural practices that intensify the land use, inputs and technological knowledge aiming increased profitability and competitiveness (Bonaudo et al., 2014; Lemaire et al., 2014).

In this context, the grain crops intercroppings with forages species allow to produce grains and straw on the soil surface or the formation of biomass for the cattle grazing (Morais et al., 2014). Thus, the intercropping of annual crops with tropical grasses, used in integrated

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crop-livestock systems, has been increasingly adopted by farmers in the Brazillian Cerrado region (Oliveira et al., 2015; Freitas et al., 2016).

However, the great difficulty of this region is keeping the straw on the soil surface in the off-season (Kliemann et al., 2006; Borghi et al., 2013; Ensinas et al., 2016). The weather conditions are a great obstacle to this system, in which is characterized by dry winter, high temperatures throughout the year and a prolonged dry season, making it difficult to keep the straw on the soil surface (Silva et al., 2015). In this context, off-season crops are essential for the implementation and feasibility of the system as they provide ground cover for a longer period (Horvathy Neto et al., 2012).

In the Cerrado region, specifically in the Brazillian Midwest, the sorghum crop became increasingly relevant to grain production. It is a crop grown after the harvest of soybean, in off-season cultivation in the no-tillage under conditions lower precipitation. The increasing of the sorghum area in that region is due to great demand of agricultural industries installed in the region and to nutritional value similar to corn. In addition, it has a lower production cost in relation to corn and excellent adaptation to different environments (Baumhardt et al., 2005; Kouressy et al., 2008), especially during the off-season, in which there are water deficits coinciding with the reproductive development of the crop. Forage grasses, such as *Brachiaria* species, are alternatives to rotation, succession or intercropping systems in the Cerrado. It can provide an excellent vegetable cover (Lima et al., 2014), contributing to increases in the levels of organic matter in the soil, beyond to make the crop rotation (Loss et al., 2013). The *Brachiaria* spp. also has an abundant root system, contributing to water infiltration, aggregation and aeration in the soil (Kluthcouski et al., 2004; Silva et al., 2015).

The intercropping of sorghum with *Brachiaria* spp., in the off-season cultivation, is a promising technique because it allows the production of grains and forages (Ribeiro et al., 2015). In the Cerrado, the success of such intercropping systems is because the straw produced provides a favorable environment for the recovery or conservation of soil properties (Entz et al., 2002; Franzluebbers, 2007) to promote an improvement of physical, chemical and biological conditions and to contribute to the production and development of plants (Maughan et al., 2009; Bell et al., 2014). Besides, the intercropping enables the consolidation of no-tillage system in the Cerrado, resulting in positive effects on crops, such as soybean grown in succession (Silva et al., 2015). However, there is a need for more information about *Brachiaria* spp. implementation recommendations, such as intercropping systems and seeding density in order to increase dry matter production in the off-season.

Thus, the objective of this study was to evaluate the effects of grain sorghum intercropped with *Brachiaria ruziziensis* that provides higher sorghum grain yield and dry mass of both cultures, in different forage seeding densities on the row, inter-row and broadcast intercropping systems, besides the evaluation of cultural performance soybean in succession.

## MATERIALS AND METHODS

### Location and experiment characterization

The experiments were conducted in the field (17°47'22.3" S, 50°57'40.1" W; altitude: 737 m) in the agricultural area of the city of Rio Verde-Goiás, Brazil. The soil of the experimental area was classified as a dystrophic Red Latosol (Santos et al., 2013). The preceding summer crop was soybean grown under no-tillage system. Before starting the experiment, the soil had the following chemical and physical characteristics: pH in $CaCl_2$: 4.6; Ca, Mg, K, Al, H+Al, and cation exchange capacity: 1.55, 1.01, 0.16, 0.25, 5.7 and 8.40 in $cmol_c$ $dm^{-3}$, respectively; P: 7.70 mg $dm^{-3}$; base and aluminum saturations: 32.25 and 8.45%, respectively; organic matter: 25.52 g $dm^{-3}$; and clay, silt and sand: 540, 170 and 290 g $kg^{-1}$, respectively. The average air temperature and rainfall during the conduction of the experiment are as shown in Figure 1.

### Experiment design

The experimental design was randomized blocks in a 3×5 factorial with four repetitions, with three *B. ruziziensis* and grain sorghum intercropping systems (row, inter-row and broadcast sowing) with five seeding density (2, 4, 6, 8 and 10 viable pure seeds $m^{-2}$), beyond the corresponding additional treatments to grain sorghum monocultures (0 density of viable pure seeds $m^{-2}$) and the five *B. ruziziensis* seeding densities. It was the grain sorghum hybrid BRS 330 (medium cycle, semi-open panicles and red grains without tannin). The *B. ruziziensis* was chosen because it has decumbent culms, short racemes, intense hairiness and good production of biomass for soil covering. The plots consisted of seven sorghum planting rows 5.0 m long and spaced 0.50 m apart. The useful area was obtained disregarding the two side rows and eliminating 0.50 m at each end.

### Experiment installation and conduction

After the soybean harvest and one week before the implementation of sorghum intercropped with *B. ruziziensis*, the desiccation of weeds was performed using the equivalent to 1,440 g a.e. $ha^{-1}$ of glyphosate and 0.5 L $ha^{-1}$ of 2,4 D with a spray volume of 150 L $ha^{-1}$. One day before sowing, the sorghum sowing furrows were marked using a seeder with a row spacing of 0.50 m. In this operation, the application of 333 kg $ha^{-1}$ of 08-20-18 fertilizer was performed. Both sorghum and *B. ruziziensis* were manually sown on March 11, 2014. The forage crop was sowed in the row intercropping system at a 10 cm depth together with the fertilizer. Then, seeds were covered with 8 cm of soil. The sorghum was sown soon after and then covered by 2 cm of soil. In the inter-row intercropping, the furrows for the sowing of *B. ruziziensis* were opened in inter-rows of sorghum at a 10 cm depth. *B. ruziziensis* was seeded by throwing in the broadcast sowing system. Then, the monocultures of sorghum and *B. ruziziensis* were sown at 2 and 10 cm of depth, respectively. To define the amount of viable pure *B. ruziziensis* seeds, a germination/emergence test was performed in a sand bed to obtain the amount of viable pure seeds per $m^2$.

At 23 days after the emergency (DAE), the coverage at the side of the sorghum sowing line with nitrogen was performed using 550 kg $ha^{-1}$ as ammonium sulfate. On the same day, 0.40 L $ha^{-1}$ of

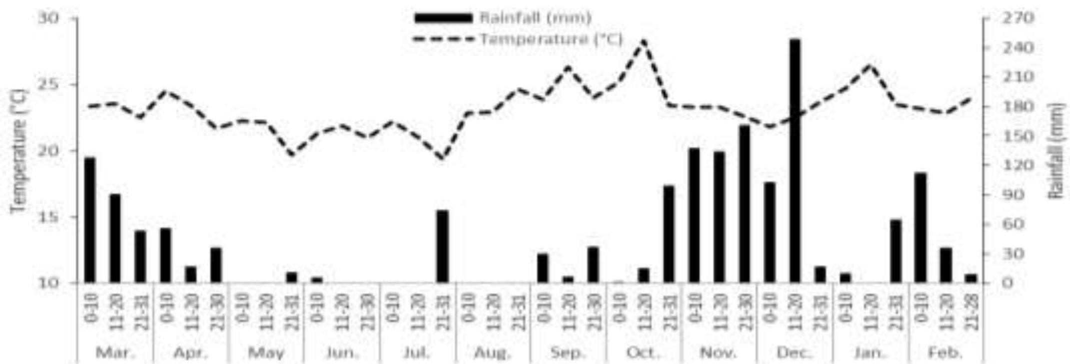


**Figure 1.** Variation of average air temperature and rainfall every ten days from March 2014 to February 2015, Rio Verde/GO, Brazil (source: Weather Station of the University of Rio Verde, Rio Verde).

bifenthrin + carbosulfan was spray mechanically. At 45 DAE, 0.20 L $ha^{-1}$ of chlorantraniliprole was used for the control of *Spodoptera frugiperda*. In both applications, a spray volume of 200 L $ha^{-1}$ was used. The harvest of sorghum was performed at 119 DAE (July 8, 2014).

### Characteristics evaluated on *B. ruziziensis* and grain sorghum crops

Grain yield (harvest of panicles, with subsequent threshing and weighing of grains; moisture was corrected to 13%), thousand grain weight (weight of a thousand grains chosen randomly in the yield sample; moisture was corrected to 13%), plant height (measured from the base of the plant to the tip of the panicles in five randomly selected plants) and final population (counting the total number of plants harvested) were evaluated in the useful area of the plot.

After the sorghum harvest, a cut was made at 30 cm height to standardize plants. The *B. ruziziensis* plants remained for 124 days in the field together with sorghum stubble. On that date, the plant height was determined (measured from the base of the plant to the tip of last fully expanded leaf in the useful area of the plots in five plants chosen randomly). At the same time, the dry matter yield of each crop and their sum were evaluated for *B. ruziziensis* and grain sorghum to quantify the production of straw. In this evaluation, the dry matter of sorghum and *B. ruziziensis* plant were measured in 1 $m^2$ using a 1.0 × 1.0 m iron square. The cut in plant was made on the soil level. The samples were placed separately in paper bags and taken to dry in an oven at 65°C to determine dry weight. Then, sorghum, *B. ruziziensis* and total dry matter yield were calculated in kg $ha^{-1}$.

Upon cutting of biomass, the percentage of soil cover was quantified by evaluation at two points chosen randomly in the useful area of the plot. A 0.50 × 0.50 m iron square, containing a line with ten equidistant points, was used. The determination of the coverage percentage of the soil surface was calculated when these points coincided with the presence of vegetable cover of the sorghum and *B. ruziziensis*.

### Soybean crop

After the harvest of *B. ruziziensis* and grain sorghum crop biomass, soybean was seeded in order to assess the performance of the crop in succession to intercropping. The desiccation of sorghum and *B. ruziziensis* biomass was mechanically performed 124 days after harvesting the sorghum using an equivalent to 1,920 g a.e. $ha^{-1}$ of glyphosate and 0.50 L $ha^{-1}$ of 2,4 D with a spray volume of 150 L $ha^{-1}$.

Six days after the desiccation of biomass (November 15, 2014), the soybean crop was implemented in the seeding furrows with a seven-line seeder and 408 kg $ha^{-1}$ of 08-20-18 fertilizer. The variety NS 7490 RR was used (early circle, indeterminate growth and tolerant to the herbicide glyphosate).

Glyphosate (960 g $ha^{-1}$) + [bifenthrin + zeta-cypermethrin] (0.25 L $ha^{-1}$) and [carbendazim + kresoxim-methyl + tebuconazole] (1.0 L $ha^{-1}$) were used at 20 DAE to control weeds, pests and diseases. The two latter products were also used at 27 DAE. For the prevention of diseases and pests, the following pesticides were also used: [carbendazim + cresoxim-methyl + tebuconazole] (1.0 L $ha^{-1}$) and [bifenthrin + carbosulfan] (0.6 L $ha^{-1}$) at 52 DAE, and [carbendazim + cresoxim-methyl + tebuconazole] (1.0 L $ha^{-1}$) and acephate (1.00 kg $ha^{-1}$) at 86 DAE. All applications were performed using a mechanical sprayer with spray volume of 150 L $ha^{-1}$.

### Characteristics evaluated on soybean crop in succession to intercropping

On soybean crop, the following was analyzed in the useful area of the plot: grain yield (plants harvest, with subsequent threshing and weighing of grains; moisture was corrected to 13%), thousand grain weight (weight of thousand grains; moisture was corrected to 13%), initial population (counting the number of plants) at the fully developed two trifoliate stage (stage $V_2$), final population (counting number of plants at harvest), initial plant, in stage $V_2$, and final plant height (measured from the soil surface to insertion on second trifoliate and on last node, respectively, in five randomly selected plants at harvest), height of insertion of the first pod (measured from the soil surface to the insertion of the first pod at harvest), number of pods on the secondary and main stems with one, two, three and four grains; number of secondary stems (counting the number of secondary stems in five randomly selected plants) and total number of pods (counting the number of pods in a same sample with five plants). The evaluations of the number of pods and secondary stems were performed at the harvest of soybean.

Firstly, an individual analysis of variance was performed and then an analysis of the data obtained in intercropping was performed combined with data from the monoculture. To compare the mean values of the intercropping, the Tukey test at 5% probability was performed to compare intercropping systems means. The values means of seeding densities were compared by regression analysis when significance was found on variance analyses. Among the means obtained in intercropping with the monoculture, a comparison by contrast using the Dunnett test at 5% probability was performed.

**Table 1.** Significance of the variables grain yield (GY), 1000-grain weight (1000-GW), plant height (SPH), plant population (POP) and dry matter yield (SDMY) of grain sorghum crop, and plant height (BPH), dry mass yield (BDMY) of *B. ruziziensis*, total dry mass yield (TDMY) and soil cover (SC) of sorghum intercropped with *B. ruziziensis* in the densities of 2, 4, 6, 8 and 10 viable pure seeds $m^{-2}$ in the 2014 off-season, Rio Verde-GO, Brazil.

| Sources of variation | FD | GY | 1000-GW | SPH | POP | SDMY |
|---|---|---|---|---|---|---|
| Intercropping systems (IS) | 2 | ns | ns | ns | ** | ns |
| Seeding density (SD) | 4 | ns | ns | ns | ns | ns |
| IS × SD | 8 | ns | ns | ns | ns | ns |
| Intercropping × Monoculture | 1 | ns | ns | ns | ns | ** |
| CV (%) | - | 20.5 | 10.7 | 4.8 | 12.9 | 32.7 |
| **Sources of variation** | **FD** | **BPH** | **BDMY** | **FD** | **TDMY** | **SC** |
| Intercropping systems (IS) | 2 | * | ns | 2 | ns | * |
| Seeding density (SD) | 4 | ns | ns | 4 | ns | ns |
| IS × SD | 8 | ns | ns | 8 | ns | ns |
| Monoculture | 4 | ns | ns | 5 | ns | ** |
| Intercropping × Monoculture | 1 | ** | ** | 1 | ns | ** |
| CV (%) | - | 10.3 | 23.3 | - | 14.2 | 8.7 |

**, * and ns: significant at 1 and 5% and not significant, respectively, by F test; CV: Variation coefficient; FD: free degree.

## RESULTS AND DISCUSSION

### Grain sorghum crop

The *B. ruziziensis* crop in the intercropping did not interfere on development and yield of the sorghum. This is evidenced by the lack of significant between intercropping systems and monoculture for the grain yield, thousand grain weight and plant height of the sorghum crop. However, the sorghum dry matter yield showed significant interaction, so *B. ruziziensis* intercropped with sorghum during off-season interfered in this trait of sorghum (Table 1). Besides, the intercropping systems influenced the sorghum plant population.

The *B. ruziziensis* and grain sorghum intercropping, under off-season conditions did not cause significant competition for water, light, nutrients and physical space. Thus, it was observed mean values similar for sorghum grain yield, thousand grain weight and plant height of sorghum crop in sorghum-based intercropping system and monoculture (Table 2).

It is noteworthy that no herbicide was applied to the intercropping to suppress the growth of *B. ruziziensis* plants, as the Cerrado region grower do in the maize crop. This is due the lack of selective grass herbicides for a post-emergence application in the sorghum crop. Moreover, it is important to note that *B. ruziziensis* has a prostrated initial growth and a slower establishment. This may have allowed sorghum plants to develop faster, without interference at the early development stage. Although, the research results are limited with regard to sorghum yield during off-season, the obtained values of grain yield allow to infer the technical feasibility of the *B. ruziziensis* and grain sorghum intercropping in succession to soybeans in the Brazilian Midwest, as evidenced by Silva et al. (2015).

The decrease in rainfall during the development of the species, associated with a slow initial growth of *B. ruziziensis*, caused the grass not to interfere with the height of sorghum plants (Table 2), corroborating with studies on sorghum intercropped with *Brachiaria* spp. (Horvathy Neto et al., 2012; Silva et al., 2015).

The analysis of plant population at the sorghum harvest is essential to establish possible effects of suppressive *B. ruziziensis* plants on the grain sorghum crop. In this respect, no significant differences were observed for plant populations between the intercropping and the monoculture (Table 2). However, differences in plant populations were observed among the intercropping systems, with lower values in the broadcast seeding. However, this did not result in differences in sorghum grain yield, as discussed earlier.

### *B. ruziziensis* crop

Intercropping with sorghum interfered in the plant height and dry mass yield of *B. ruziziensis* relative to values of forage monoculture ($P \leq 0.05$) (Table 1). In the row and inter-row intercropping systems, the sorghum shading, causing etiolation, resulted in higher *B. ruziziensis* height, unlike the broadcast intercropping (Table 3). Consequently, most of the intercropping systems showed results lower for dry matter yield of *B. ruziziensis* in the intercropping.

After the harvest of sorghum grains, because of the low regrowth of sorghum plants during off-season, the lack of rain in the Cerrado (Figure 1) and the presence of *B. ruziziensis* plants at the vegetative stage causing suppression of sorghum plants in intercropping. Thus, the

**Table 2.** Mean values for grain yield (GY), 1000-grain weight (1000-GW), plant height (SPH), plant population (POP) and dry matter yield (SDMY) of grain sorghum crop intercropped with *B. ruziziensis* in the densities of 2, 4, 6, 8 and 10 viable pure seeds m$^{-2}$ in the 2014 off-season, Rio Verde-GO, Brazil.

| **Intercropping systems** | **Seeding density (viable pure seeds m$^{-2}$)** | | | | | **Mean values** |
|---|---|---|---|---|---|---|
| | **2** | **4** | **6** | **8** | **10** | |
| **GY (kg ha$^{-1}$)** | | | | | | |
| Row | 2,663$^{a}$ | 2,050$^{a}$ | 2,295$^{a}$ | 2,336$^{a}$ | 2,383$^{a}$ | 2,345$^{a}$ |
| Inter-row | 2,285$^{a}$ | 2,295$^{a}$ | 2,428$^{a}$ | 2,089$^{a}$ | 2,087$^{a}$ | 2,237$^{a}$ |
| Broadcast | 2,048$^{a}$ | 2,151$^{a}$ | 2,303$^{a}$ | 2,345$^{a}$ | 2,282$^{a}$ | 2,226$^{a}$ |
| Mean values | 2,332 | 2,165 | 2,342 | 2,257 | 2,251 | 2,269 |
| Monocultures | | | 2,028 | | | |
| **1000-GW (g)** | | | | | | |
| Row | 12.56$^{a}$ | 13.04$^{a}$ | 12.29$^{a}$ | 12.56$^{a}$ | 12.54$^{a}$ | 12.60$^{a}$ |
| Inter-row | 12.48$^{a}$ | 12.27$^{a}$ | 12.22$^{a}$ | 11.47$^{a}$ | 11.83$^{a}$ | 12.05$^{a}$ |
| Broadcast | 11.02$^{a}$ | 11.91$^{a}$ | 12.06$^{a}$ | 12.65$^{a}$ | 11.78$^{a}$ | 11.89$^{a}$ |
| Mean values | 12.02a | 12.41 | 12.19 | 12.23 | 12.05 | 12.18 |
| Monocultures | | | 13.09 | | | |
| **SPH (cm)** | | | | | | |
| Row | 129$^{a}$ | 132$^{a}$ | 129$^{a}$ | 130$^{a}$ | 133$^{a}$ | 131$^{a}$ |
| Inter-row | 130$^{a}$ | 132$^{a}$ | 132$^{a}$ | 131$^{a}$ | 132$^{a}$ | 131$^{a}$ |
| Broadcast | 129$^{a}$ | 129$^{a}$ | 128$^{a}$ | 130$^{a}$ | 128$^{a}$ | 129$^{a}$ |
| Mean values | 129 | 131 | 130 | 130 | 131 | 130 |
| Monocultures | | | 126 | | | |
| **POP (plants ha$^{-1}$)** | | | | | | |
| Row | 145,778$^{a}$ | 139,000$^{a}$ | 138,333$^{ab}$ | 141,667$^{a}$ | 148,000$^{a}$ | 142,556$^{a}$ |
| Inter-row | 139,667$^{a}$ | 150,000$^{a}$ | 168,999$^{a}$ | 147,333$^{a}$ | 164,444$^{a}$ | 154,089$^{a}$ |
| Broadcast | 133,000$^{a}$ | 141,000$^{a}$ | 117,999$^{b}$ | 142,667$^{a}$ | 108,000$^{b}$ | 128,533$^{b}$ |
| Mean values | 139,481 | 143,333 | 141,777 | 143,888 | 140,148 | 141,170 |
| Monocultures | | | 131,333 | | | |
| **SDMY (kg ha$^{-1}$)** | | | | | | |
| Row | 1,108$^{a*1}$ | 1,143$^{a*1}$ | 1,126$^{a*1}$ | 1,332$^{a*1}$ | 1,110$^{a*1}$ | 1,164$^{a}$ |
| Inter-row | 1,214$^{a*1}$ | 1,456$^{a}$ | 1,256$^{a*1}$ | 1,080$^{a*1}$ | 1,312$^{a*1}$ | 1,263$^{a}$ |
| Broadcast | 1,251$^{a*1}$ | 1,288$^{a*1}$ | 1,342$^{a*1}$ | 1,127$^{a*1}$ | 2,362$^{a}$ | 1,474$^{a}$ |
| Mean values | 1,191 | 1,296 | 1,241 | 1,180 | 1,595 | 1,300 |
| Monocultures | | | 2,365 | | | |

Means followed by the same lowercase letter in columns do not differ by Tukey test at 5% probability. $*^{1}$: Means differ significantly from the sorghum monoculture by Dunnett test at 5% probability.

most intercropping treatments showed lower mean values of dry mass of *B. ruziziensis* that the monoculture these forage crop (Table 3).

## Dry matter production in the intercropping

The intercropping systems and monocultures showed similar mean values for total dry mass yield without decreasing the grain yield in the sorghum-based intercropping systems (Tables 1 and 3). However, the intercropping systems showed significant difference for the soil cover (SC). In this trait, the row intercropping system showed higher mean values than broadcast sowing intercropping system (Table 3). Also, the grain sorghum monoculture showed lower soil cover compared to *B. ruziziensis*.

The intercropping and monoculture interaction showed significant difference for the soil cover (Table 1). The row intercropping system and *B. ruziziensis* monoculture

**Table 3.** Mean values for plant height (BPH) and dry matter yield (BDMY) of *B. ruziziensis*, total dry mass yield (TDMY) and soil cover (SC) of the grain sorghum intercropping with *B. ruziziensis* in the densities of 2, 4, 6, 8 and 10 viable pure seeds $m^{-2}$ in the 2014 off-season, Rio Verde-GO, Brazil.

| Intercropping systems | Seeding density (viable pure seeds $m^{-2}$) | | | | | Mean values |
|---|---|---|---|---|---|---|
| | 2 | 4 | 6 | 8 | 10 | |
| **BPH (m)** | | | | | | |
| Row | $1.06^{a*1}$ | $1.12^{a*1}$ | $1.15^{a*1}$ | $1.04^{a*1}$ | $1.18^{a*1}$ | $1.11^{a}$ |
| Inter-row | $1.07^{a*1}$ | $1.08^{a*1}$ | $1.10^{a*1}$ | $1.07^{a*1}$ | $1.12^{a*1}$ | $1.09^{a}$ |
| Broadcast | $0.89^{a*1}$ | $0.97^{a}$ | $0.96^{a}$ | $1.04^{a*1}$ | $1.02^{a}$ | $0.98^{b}$ |
| Mean values | 1.01 | 1.06 | 1.07 | 1.05 | 1.11 | 1.06 |
| Monocultures | $0.64^{A}$ | $0.76^{A}$ | $0.77^{A}$ | $0.74^{A}$ | $0.85^{A}$ | - |
| **BDMY (kg $ha^{-1}$)** | | | | | | |
| Row | $2,693^{a}$ | $2,337^{a}$ | $2,330^{a*1}$ | $2,435^{a}$ | $2,261^{a*1}$ | $2,411^{a}$ |
| Inter-row | $2,148^{a*1}$ | $2,572^{a}$ | $2,171^{a*1}$ | $2,459^{a}$ | $2,372^{a*1}$ | $2,345^{a}$ |
| Broadcast | $1,582^{a*1}$ | $1,925^{a*1}$ | $1,990^{a*1}$ | $2,234^{a}$ | $2,344^{a*1}$ | $2,015^{a}$ |
| Mean values | 2,141 | 2,278 | 2,163 | 2,376 | 2,326 | 2,257 |
| Monocultures | 3,945 | 3,543 | 3,725 | 3,423 | 4,014 | - |
| **TDMY (kg $ha^{-1}$)** | | | | | | |
| Row | $3,801^{a}$ | $3,480^{a}$ | $3,456^{a}$ | $3,767^{a}$ | $3,371^{a}$ | $3,575^{a}$ |
| Inter-row | $3,363^{a}$ | $4,028^{a}$ | $3,427^{a}$ | $3,539^{a}$ | $3,684^{a}$ | $3,608^{a}$ |
| Broadcast | $2,833^{a}$ | $3,213^{a}$ | $3,332^{a}$ | $3,361^{a}$ | $4,706^{a}$ | $3,489^{a}$ |
| Mean values | 3,332 | 3574 | 3,405 | 3,556 | 3,920 | Sorgo |
| Monocultures | $3,945^{A}$ | $3,543^{A}$ | $3,725^{A}$ | $3,412^{A}$ | $4,014^{A}$ | $2,566^{A}$ |
| **SC (%)** | | | | | | |
| Row | $80.0^{a}$ | $81.2^{a}$ | $80.0^{a}$ | $88.7^{a}$ | $82.5^{a}$ | $82.5^{a}$ |
| Inter-row | $72.5^{a*1}$ | $77.5^{a*1}$ | $80.0^{a}$ | $82.5^{a}$ | $82.5^{a}$ | $79.0^{ab}$ |
| Broadcast | $75.0^{a*1}$ | $73.7^{a*1}$ | $73.7^{a*1}$ | $72.5^{a*1}$ | $77.5^{a*1}$ | $74.5^{b}$ |
| Mean values | 75.8 | 77.5 | 77.9 | 81.2 | 80.8 | Sorgo |
| Monocultures | $96.2^{A}$ | $97.5^{A}$ | $97.5^{A}$ | $100.0^{A}$ | $100.0^{A}$ | $78.75^{B}$ |

Means followed by the same lowercase letter in lines and upper case letter in columns do not differ by Tukey test at 5% probability. *[1; 2]: Means differ significantly from the *B. ruziziensis* and sorghum monocultures, respectively, by Dunnett test at 5% probability.

showed similar mean values for the soil cover in the five different seeding density (Table 3). The contrast was observed to broadcast sowing intercropping (lower values; P≤0.05). The similar mean values to the first system could be due the fact that the forage crop in the intercropping was benefited by fertilization; it could favor the vegetative growth and consequently the covering of the soil surface.

However, the inter-row intercropping system showed lower mean values (P≤0.05) for the soil cover than *B. ruziziensis* monoculture only for the seeding density 2 and 4 seeds $m^{-2}$. In the higher seeding density (6, 8, and 10 seeds $m^{-2}$), those treatments did not show significant difference relative to monoculture. Thus, the *B. ruziziensis* growth, after the sorghum crop, when grown in row and inter-row intercropping in succession to soybeans crop, enables to increase the biomass production in intercropping the Cerrado soil, as observed in other researches (Horvath Neto, 2012; Silva et al., 2015).

It is worth noting that, during the off-season in the Brazillian midwest region, due the low rainfall (Figure 1), the pastures for cattle grazing are debilitated. The production of biomass during this period using inter-cropping systems, like *B. ruziziensis* and grain sorghum intercropping, will enable the production of forage. If the stocking rate is respected and high levels of animal unit are not adopted, the biomasses of *B. ruziziensis* and sorghum can be used as grazing. Otherwise, this biomass may be desiccated in advanced time, since this forage species is easily desiccated compared other *Brachiaria* spp. for the implementation of soybean crop (Ceccon and Concenço, 2014).

In addition, the *B. ruziziensis* and grain sorghum intercropping systems and sorghum monoculture showed similar mean values for grain yield, as discussed previously. The row and inter-row (6, 8, and 10 seeds $m^{-2}$) intercropping systems and *B. ruziziensis* monoculture showed similar mean values for the soil cover, proving

**Table 4.** Significance of the variables grain yield (GY), 1000-grain weight (1000-GW), initial (IPOP) and final plant populations (FPOP), initial (IPH) and final plant heights (FPH), first pod insertion heights (FPIH), number of pods on the main stem with one (NPMS1G), two (NPMS2G), three (NPMS3G) and four grains (NPMS4G) and in secondary stems with one (NPSS1G), two (NPSS2G) three (NPSS3G) and four grains (NPSS4G), number of secondary stems (NSS) and number of pods total per plant (NPT) for soybean grown in succession to grain sorghum intercropped with *B. ruziziensis* in the densities of 2, 4, 6, 8 and 10 viable pure seeds $m^{-2}$ in the 2014 off-season, Rio Verde-GO, Brazil.

| Sources of variation | FD | GY | 1000-GW | IPOP | FPOP | IPH | FPH | FPIH | NPMS 1G |
|---|---|---|---|---|---|---|---|---|---|
| Intercropping systems (IS) | 2 | ns | * | ns | ns | ns | ns | ns | ns |
| Seeding Density (SD) | 4 | ns | ns | ns | ** | ns | ns | ns | ns |
| IS × SD | 8 | ns | ns | ns | * | ns | ns | ns | ns |
| Monoculture | 4 | ns | ns | ns | ns | ns | ns | ns | ns |
| Intercropping × Monoculture | 1 | ns | ns | ns | * | ns | ns | * | ns |
| CV (%) | | 11.35 | 9.46 | 8.81 | 5.59 | 11.14 | 7.58 | 8.58 | 69.5 |

| Sources of variation | FD | NPMS 2G | NPMS 3G | NPMS 4G | NPSS 1G | NPSS 2G | NPSS 3G | NPSS 4G | NSS | NPT |
|---|---|---|---|---|---|---|---|---|---|---|
| Intercropping systems (IS) | 2 | ns | ns | ns | ns | ns | ns | ns | * | ns |
| Seeding Density (SD) | 4 | ns | ns | ns | ns | ns | ns | ns | ns | ns |
| IS × SD | 8 | ns | ns | ns | ns | ns | ns | ns | ns | ns |
| Monoculture | 4 | ns | ns | ns | ns | ns | ns | ns | ns | ns |
| Intercropping × Monoculture | 1 | ns | ns | ns | ns | ns | ns | ns | ns | ns |
| CV (%) | | 55.22 | 23.87 | 46.67 | 117.69 | 51.17 | 64.49 | 125.18 | 42.16 | 23.1 |

**, * and ns: significant at 1% and 5% and not significant, respectively, by F test; CV: Variation coefficient; FD: free degree.

the importance of forage species in the intercropping to benefit the soil conservation in the no-tillage system (Kluthcouski et al., 2004).

## Soybean crop

Once collected, the *B. ruziziensis* and sorghum biomass, desiccation was done for both species and six day later, the soybean crop was seeded. The results revealed that the intercropping did not affect (P≥0.05) the grain yield, initial population, initial and final plant heights and yield components (number of pods on the main and secondary stems, regardless of the number of grains) (Table 4). However, the broadcast sowing intercropping provided a greater thousand grain weight in relation to the inter-row intercropping (Table 5). Even so, this difference did not contribute to the increase in the grain yields of soybean crop.

The grains yield of soybean was not influenced by preceding crop [*B. ruziziensis* and grain sorghum intercropping systems and monocultures (grain sorghum or *B. ruziziensis*)], type of intercropping system, nor sowing density of *B. ruziziensis* (Table 5). Some case registers an increase in the yield of the culture successor to the intercropping system (Morais et al., 2014). The benefits of forage grass intercropping have been observed on the soil structure by using plants that have a large and aggressive root system with different geometries and soil spaces exploited, besides providing a greater vegetation cover (Kluthcouski et al., 2004).

The fact that total dry matter yield and soil cover values in intercropping is not differentiate from the monoculture of sorghum which might have led to the absence of response in the soybean yield. It is important to note that from mid-December until the end of January, there was a drastic reduction in rainfall in the region, with dry periods in the first twenty days of January (Figure 1). During this period, the soybean was at the reproductive stage, namely pod formation and early grain filling, which require more water. Thus, the higher percentage of soil cover provided by the straw favors the retention of moisture in the soil during the development of the summer crop, especially under drought conditions (Yin et al., 2016).

It was expected that the straw on the soil surface might influence the early development of soybeans, but it did not. Perhaps this is justified by the lack of differences in total dry matter yield, as discussed earlier. Consequently, the initial plant heights were not affected by the implementation systems and the seeding density of *B. ruziziensis* (Tables 1 and 5). Similarly, there were no significant differences from the results obtained in relation to the monoculture (Table 5). The same effect was observed for the insertion height of the first pod and plant height (Table 7). Although a linear increase in the final population of soybean was observed with the increase in the seeding density of *B. ruziziensis* in row intercropping, there were no increases in the yield of soybeans (Table 6).

The analysis of the other yield components (number of pods in the main and secondary stems, regardless of the

**Table 5.** Average values for grain yield (GY), 1000-grain weight (1000-GW), initial (IPOP) and final populations (FPOP) and initial plant height (IPH) of soybean crop in succession to grain sorghum intercropped with *B. ruziziensis* in the densities of 2, 4, 6, 8 and 10 viable pure seeds m$^{-2}$ in the 2014 off-season, Rio Verde-GO, Brazil.

| Intercropping systems | Seeding density (viable pure seeds m$^{-2}$) | | | | | Mean values |
|---|---|---|---|---|---|---|
| | 2 | 4 | 6 | 8 | 10 | |
| **GY (kg ha$^{-1}$)** | | | | | | |
| Row | 2,928$^{a}$ | 2,488$^{a}$ | 2,703$^{a}$ | 2,802$^{a}$ | 3,047$^{a}$ | 2,793$^{a}$ |
| Inter-row | 2,744$^{a}$ | 2,815$^{a}$ | 2,366$^{a}$ | 2,712$^{a}$ | 2,881$^{a}$ | 2,703$^{a}$ |
| Broadcast | 2,633$^{a}$ | 2,548$^{a}$ | 2,773$^{a}$ | 2,579$^{a}$ | 2,542$^{a}$ | 2,615$^{a}$ |
| Mean values | 2,768 | 2,617 | 2,614 | 2,698 | 2,823 | Sorgo |
| Monocultures | 2,813$^{A}$ | 2,601$^{A}$ | 2,966$^{A}$ | 2,633$^{A}$ | 2,614$^{A}$ | 2,482$^{A}$ |
| | | | | | | |
| **1000-GW (g)** | | | | | | |
| Row | 114$^{a}$ | 112$^{a}$ | 115$^{a}$ | 99$^{a}$ | 113$^{a}$ | 111$^{ab}$ |
| Inter-row | 116$^{a}$ | 99$^{a}$ | 110$^{a}$ | 106$^{a}$ | 99$^{a}$ | 106$^{b}$ |
| Broadcast | 117$^{a}$ | 113$^{a}$ | 125$^{a}$ | 115$^{a}$ | 109$^{a}$ | 116$^{a}$ |
| Mean values | 116 | 108 | 117 | 107 | 107 | Sorgo |
| Monocultures | 114$^{A}$ | 111$^{A}$ | 115$^{A}$ | 108$^{A}$ | 120$^{A}$ | 107$^{A}$ |
| | | | | | | |
| **IPOP (plants ha$^{-1}$)** | | | | | | |
| Row | 424,375$^{a}$ | 448,125$^{a}$ | 480,832$^{a}$ | 436,665$^{a}$ | 448,125$^{a}$ | 447,624$^{a}$ |
| Inter-row | 470,625$^{a}$ | 495,625$^{a}$ | 447,500$^{a}$ | 463,125$^{a}$ | 458,750$^{a}$ | 467,125$^{a}$ |
| Broadcast | 432,500$^{a}$ | 431,250$^{a}$ | 455,000$^{a}$ | 429,375$^{a}$ | 444,375$^{a}$ | 438,500$^{a}$ |
| Mean values | 442,500 | 458,333 | 461,110 | 443055 | 450,416 | Sorgo |
| Monocultures | 425,000$^{A}$ | 416,875$^{A}$ | 446,250$^{A}$ | 405,000$^{A}$ | 438,750$^{A}$ | 437,708$^{A}$ |
| | | | | | | |
| **FPOP (plants ha$^{-1}$)** | | | | | | |
| Row | 359,166$^{a*1}$ | 395,625$^{a}$ | 435,625$^{a*2}$ | 391,875$^{a}$ | 405,000$^{a}$ | 397,458$^{a}$ |
| Inter-row | 403,750$^{a}$ | 396,250$^{a}$ | 415,625$^{a}$ | 430,625$^{a*1}$ | 420,000$^{a}$ | 413,250$^{a}$ |
| Broadcast | 379,582$^{a}$ | 403,760$^{a}$ | 394,166$^{a}$ | 396,875$^{a}$ | 389,375$^{a}$ | 392,749$^{a}$ |
| Mean values | 380,833 | 398,542 | 415,139 | 406,458 | 404,792 | Sorgo |
| Monocultures | 420,000$^{A}$ | 368,125$^{A}$ | 393,750$^{A}$ | 381,875$^{A}$ | 393,125$^{A}$ | 386,458$^{A}$ |
| | | | | | | |
| **IPH (cm)** | | | | | | |
| Row | 17.15$^{a}$ | 16.30$^{a}$ | 15.30$^{a}$ | 16.42$^{a}$ | 16.12$^{a}$ | 16.26$^{a}$ |
| Inter-row | 16.52$^{a}$ | 17.37$^{a}$ | 15.15$^{a}$ | 15.67$^{a}$ | 14.60$^{a}$ | 15.86$^{a}$ |
| Broadcast | 15.85$^{a}$ | 16.80$^{a}$ | 15.22$^{a}$ | 16.02$^{a}$ | 14.90$^{a}$ | 15.26$^{a}$ |
| Mean values | 16.51 | 16.82 | 15.22 | 16.04 | 15.21 | Sorgo |
| Monocultures | 17.32$^{A}$ | 17.27$^{A}$ | 17.05$^{A}$ | 18.40$^{A}$ | 16.85$^{A}$ | 15.65$^{A}$ |

Means followed by the same lowercase letter in lines and upper case letter in columns do not differ by Tukey test at 5% probability. *$^{1;\ 2}$: Means differ significantly from the *B. ruziziensis* and sorghum monocultures, respectively, by Dunnett test at 5% probability.

**Table 6.** Models, coefficient of determination ($R^2$) and significance (P value) of regressions adjusted for the characteristic final plant population (FPOP) of soybeans crop grown in succession to sorghum intercropped with *B. ruziziensis* in the densities of 2, 4, 6, 8 and 10 viable pure seeds m$^{-2}$ in the 2014 off-season, Rio Verde-GO, Brazil.

| Intercropping systems | Models | $R^2$ | P (value) (%) |
|---|---|---|---|
| **FPOP** | | | |
| Row | Y = 376.408,76 + 3669,63x | 29,15 | 9 |
| Inter-row | Unadjusted | - | - |
| Broadcast | Unadjusted | - | - |
| Mean values | Y = 385.479,40 + 2644,85x | 58,53 | 5 |

**Table 7.** Average values for final plant height (FPH), insertion height of the first pod (FPIH), number of pods on the main stem with one (NPMS1G), two (NPMS2G), three (NPMS3G) and four grains (NPMS4G) of soybean crop grown in succession to sorghum intercropped with *B. ruziziensis* in the densities of 2, 4, 6, 8 and 10 viable pure seeds m$^{-2}$ in the 2014 off-season, Rio Verde-GO, Brazil.

| Intercropping systems | Seeding density (viable pure seeds m$^{-2}$) | | | | | Mean values |
|---|---|---|---|---|---|---|
| | 2 | 4 | 6 | 8 | 10 | |
| **FPH (cm)** | | | | | | |
| Row | 62.90$^{a}$ | 58.77$^{a}$ | 62.52$^{a}$ | 62.77$^{a}$ | 62.77$^{a}$ | 61.95$^{a}$ |
| Inter-row | 59.02$^{a}$ | 62.87$^{a}$ | 61.47$^{a}$ | 62.07$^{a}$ | 64.27$^{a}$ | 61.94$^{a}$ |
| Broadcast | 57.15$^{a}$ | 63.62$^{a}$ | 64.62$^{a}$ | 59.15$^{a}$*$^{1}$ | 56.27$^{a}$*$^{1}$ | 60.16$^{a}$ |
| Mean values | 59.69 | 61.75 | 62.87 | 61.33 | 61.10 | Sorgo |
| Monocultures | 64.40$^{A}$ | 66.27$^{A}$ | 69.90$^{A}$ | 69.22$^{A}$ | 68.75$^{A}$ | 62.27$^{A}$ |
| **FPIH (cm)** | | | | | | |
| Row | 16.27$^{a}$ | 14.90$^{a}$ | 16.52$^{a}$ | 16.42$^{a}$ | 16.20$^{a}$ | 16.06$^{a}$ |
| Inter-row | 16.45$^{a}$ | 16.40$^{a}$ | 16.15$^{a}$ | 15.62$^{a}$*$^{1}$ | 15.85$^{a}$ | 16.09$^{a}$ |
| Broadcast | 16.80$^{a}$ | 16.47$^{a}$ | 17.50$^{a}$ | 16.32$^{a}$ | 15.10$^{a}$ | 16.44$^{a}$ |
| Mean values | 16.51 | 15.92 | 16.72 | 16.12 | 15.72 | Sorgo |
| Monocultures | 16.85$^{A}$ | 16.72$^{A}$ | 16.87$^{A}$ | 18.57$^{A}$ | 17.67$^{A}$ | 16.87$^{A}$ |
| **NPMS1G** | | | | | | |
| Row | 1.10$^{a}$ | 1.00$^{a}$ | 1.00$^{a}$ | 1.65$^{a}$ | 0.90$^{a}$ | 1.13$^{a}$ |
| Inter-row | 1.25$^{a}$ | 1.03$^{a}$ | 1.05$^{a}$ | 0.70$^{a}$ | 1.00$^{a}$ | 1.01$^{a}$ |
| Broadcast | 0.60$^{a}$ | 1.20$^{a}$ | 1.35$^{a}$ | 1.02$^{a}$ | 0.70$^{a}$ | 0.97$^{a}$ |
| Mean values | 0.98 | 1.08 | 1.17 | 1.12 | 0.87 | Sorgo |
| Monocultures | 0.65$^{A}$ | 1.30$^{A}$ | 1.22$^{A}$ | 0.90$^{A}$ | 1.15$^{A}$ | 1.12$^{A}$ |
| **NPMS2G** | | | | | | |
| Row | 4.45$^{a}$ | 3.55$^{a}$ | 2.60$^{a}$ | 7.50$^{a}$ | 4.05$^{a}$ | 4.43$^{a}$ |
| Inter-row | 3.55$^{a}$ | 3.73$^{a}$ | 3.35$^{a}$ | 3.35$^{a}$ | 3.65$^{a}$ | 3.53$^{a}$ |
| Broadcast | 4.15$^{a}$ | 4.50$^{a}$ | 3.51$^{a}$ | 3.67$^{a}$ | 3.00$^{a}$ | 3.77$^{a}$ |
| Mean values | 4.05 | 3.93 | 3.15 | 4.84 | 3.56 | Sorgo |
| Monocultures | 3.15$^{A}$ | 4.90$^{A}$ | 3.51$^{A}$ | 4.20$^{A}$ | 4.05$^{A}$ | 4.25$^{A}$ |
| **NPMS3G** | | | | | | |
| Row | 10.60$^{a}$ | 9.95$^{a}$ | 10.45$^{a}$ | 8.90$^{a}$ | 10.30$^{a}$ | 10.04$^{a}$ |
| Inter-row | 7.20$^{a}$ | 9.76$^{a}$ | 10.70$^{a}$ | 9.70$^{a}$ | 11.10$^{a}$ | 9.69$^{a}$ |
| Broadcast | 10.43$^{a}$ | 10.05$^{a}$ | 12.00$^{a}$ | 8.27$^{a}$ | 9.25$^{a}$ | 10.00$^{a}$ |
| Mean values | 9.41 | 9.92 | 11.05 | 8.96 | 10.22 | Sorgo |
| Monocultures | 9.50$^{A}$ | 10.70$^{A}$ | 10.97$^{A}$ | 9.10$^{A}$ | 9.85$^{A}$ | 11.22$^{A}$ |
| **NPMS4G** | | | | | | |
| Row | 1.55$^{a}$ | 1.50$^{a}$ | 2.15$^{a}$ | 2.40$^{a}$ | 2.05$^{a}$ | 1.93$^{a}$ |
| Inter-row | 1.55$^{a}$ | 1.11$^{a}$ | 2.05$^{a}$ | 1.50$^{a}$ | 1.85$^{a}$ | 1.61$^{a}$ |
| Broadcast | 2.05$^{a}$ | 2.35$^{a}$ | 2.18$^{a}$ | 2.55$^{a}$ | 2.20$^{a}$ | 2.27$^{a}$ |
| Mean values | 1.72 | 1.65 | 2.13 | 2.15 | 2.03 | Sorgo |
| Monocultures | 2.40$^{A}$ | 2.65$^{A}$ | 2.48$^{A}$ | 1.95$^{A}$ | 2.55$^{A}$ | 2.07$^{A}$ |

Means followed by the same lowercase letter in lines and upper case letter in columns do not differ by Tukey test at 5% probability.
*$^{1; 2}$: Means differ significantly from the *B. ruziziensis* and sorghum monocultures, respectively, by Dunnett test at 5% probability.

number of grains and the number of pods) were not influenced by the intercropping systems and the seeding density of *B. ruziziensis* (Tables 7 and 8). Differences were only observed for the number of secondary stems, with a higher value in broadcast sowing intercropping in relation to row intercropping (Table 8). This variation may be attributed to the phenotypic plasticity of the soybean crop in function of the population of plants used.

**Table 8.** Average values for number of pods on the secondary stem with one (NPSS1G), two (NPSS2G), three (NPSS3G) and four grains (NPSS4G) and number of secondary stems (NSS) and pods total per plant (NPT) of soybean crop grown in succession to sorghum intercropped with *B. ruziziensis* in the densities of 2, 4, 6, 8 and 10 viable pure seeds m$^{-2}$ in the 2014 off-season, Rio Verde-GO, Brazil.

| Intercropping systems | Seeding density (viable pure seeds m$^{-2}$) | | | | | Mean values |
|---|---|---|---|---|---|---|
| | 2 | 4 | 6 | 8 | 10 | |
| **NPSS1G** | | | | | | |
| Row | 0.30$^a$ | 0.60$^a$ | 0.40$^a$ | 1.65$^a$ | 0.85$^a$ | 0.76$^a$ |
| Inter-row | 0.50$^a$ | 0.45$^a$ | 0.30$^a$ | 0.30$^a$ | 0.55$^a$ | 0.42$^a$ |
| Broadcast | 0.53$^a$ | 0.40$^a$ | 0.62$^a$ | 0.52$^a$ | 0.50$^a$ | 0.52$^a$ |
| Mean values | 0.44 | 0.48 | 0.44 | 0.82 | 0.63 | Sorgo |
| Monocultures | 0.25$^A$ | 0.35$^A$ | 0.51$^A$ | 0.65$^A$ | 0.95$^A$ | 0.57$^A$ |
| **NPSS2G** | | | | | | |
| Row | 2.50$^a$ | 2.78$^a$ | 2.00$^a$ | 0.95$^a$ | 2.25$^a$ | 2.09$^a$ |
| Inter-row | 2.25$^a$ | 1.56$^a$ | 1.45$^a$ | 1.55$^a$ | 2.15$^a$ | 1.79$^a$ |
| Broadcast | 2.07$^a$ | 2.35$^a$ | 2.11$^a$ | 1.40$^a$ | 2.07$^a$ | 2.00$^a$ |
| Mean values | 2.27 | 2.23 | 1.85 | 1.30 | 2.15 | Sorgo |
| Monocultures | 1.65$^A$ | 1.60$^A$ | 1.61$^A$ | 2.30$^A$ | 2.25 $^A$ | 2.50$^A$ |
| **NPSS3G** | | | | | | |
| Row | 2.70$^a$ | 5.00$^a$ | 4.85$^a$ | 2.05$^a$ | 3.90$^a$ | 3.70$^a$ |
| Inter-row | 2.70$^a$ | 1.81$^a$ | 3.15$^a$ | 2.45$^a$ | 3.85$^a$ | 2.79$^a$ |
| Broadcast | 3.58$^a$ | 4.65$^a$ | 3.77$^a$ | 1.92$^a$ | 3.35$^a$ | 3.45$^a$ |
| Mean values | 2.99 | 3.82 | 3.92 | 2.14 | 3.70 | Sorgo |
| Monocultures | 3.85$^A$ | 2.70$^A$ | 3.37$^A$ | 2.90$^A$ | 4.70$^A$ | 3.67$^A$ |
| **NPSS4G** | | | | | | |
| Row | 0.20$^a$ | 0.50$^a$ | 0.80$^a$ | 0.15$^a$ | 0.55$^a$ | 0.80$^a$ |
| Inter-row | 0.10$^a$ | 0.36$^a$ | 0.55$^a$ | 0.65$^a$ | 0.50$^a$ | 0.43$^a$ |
| Broadcast | 0.66$^a$ | 1.65$^a$ | 0.83$^a$ | 0.55$^a$ | 0.30$^a$ | 0.44$^a$ |
| Mean values | 0.32 | 0.83 | 0.72 | 0.45 | 0.45 | Sorgo |
| Monocultures | 0.40$^A$ | 0.50$^A$ | 0.91$^A$ | 0.30$^A$ | 0.60$^A$ | 0.47$^A$ |
| **NSS** | | | | | | |
| Row | 2.10$^a$ | 2.80$^a$ | 2.85$^a$ | 2.05$^a$ | 2.30$^a$ | 2.42$^a$b |
| Inter-row | 1.80$^a$ | 1.48$^a$ | 2.00$^a$ | 1.55$^a$ | 2.20$^a$ | 1.80b |
| Broadcast | 2.96$^a$ | 2.85$^a$ | 2.87$^a$ | 2.22$^a$ | 2.32$^a$ | 2.64$^a$ |
| Mean values | 2.28 | 2.37 | 2.57 | 1.94 | 2.27 | Sorgo |
| Monoculture | 2.30$^A$ | 2.15$^A$ | 2.13$^A$ | 1.70$^A$ | 3.25$^A$ | 2.82$^A$ |
| **NPT** | | | | | | |
| Row | 23.40$^a$ | 24.88$^a$ | 24.35$^a$ | 25.25$^a$ | 24.85$^a$ | 24.54$^a$ |
| Inter-row | 19.10$^a$ | 19.83$^a$ | 22.60$^a$ | 20.20 | 24.65$^a$ | 21.27$^a$ |
| Broadcast | 24.10$^a$ | 27.10$^a$ | 26.40$^a$ | 19.92$^a$ | 21.37 | 23.79$^a$ |
| Mean values | 22.20 | 23.95 | 24.45 | 21.79 | 23.62 | Sorgo |
| Monocultures | 21.85$^A$ | 24.70$^A$ | 24.61$^A$ | 22.30$^A$ | 26.10$^A$ | 25.87$^A$ |

Means followed by the same lowercase letter in lines and upper case letter in columns do not differ by Tukey test at 5% probability.
*[1; 2]: Means differ significantly from the *B. ruziziensis* and sorghum monocultures, respectively, by Dunnett test at 5% probability.

However, the variation in the number of pods did not influence the soybean yield.

Therefore, the *B. ruziziensis* seeding did not density not affected the sorghum grain and dry matter yields in the off-season. This suggests that, under off-season conditions in the Brazillian Cerrado, it is possible to increase the seeding density these forage specie to increase the dry matter production on intercropping, without, however, causing decrease in the sorghum grain yield and of the soybean crop grown in succession. By conducting other field experiments under conditions similar, it is believed to be feasible to increase the *B. ruziziensis* seeding density above of 10 viable pure seeds $m^{-2}$ in the intercropping in off-season cultivation.

The increase in biomass production on the soil surface would help to minimize the risk of crop losses caused by dry and temperature high periods, which are common in the Brazillian midwest region. In addition, the highest amount of biomass produced in intercropping will contribute to the maintenance of the no-tillage system. Therefore, sorghum intercropped with *B. ruziziensis* on rows, inter-rows and broadcast sowing are viable cultivation techniques for a no-tillage system aiming at the production of grains and dry matter (straw) in the Cerrado region.

## Conclusions

Intercropping systems and the seeding density of *B. ruziziensis* until 10 viable pure seeds $m^{-2}$ did not affect the sorghum grains yield in the off-season cultivation, as soybean crop grown in succession.

The *B. ruziziensis* and grain sorghum intercropping was effective in producing straw on soil surface to Cerrado no-tillage system.

## Conflict of Interests

The authors have not declared any conflict of interests.

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