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Establishment of paiaguas palisadegrass in monoculture or in an integration system with other crops

Implantação do capim paiaguás em monocultivo ou em sistema de integração com outras culturas

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Abstract

The objective of this study was to evaluate the productive and structural characteristics of Paiaguas palisadegrass established in monoculture and intercropped with agricultural crops in 2018 and 2019. The evaluated treatments were: Paiaguas palisadegrass (PP) in monoculture, PP intercropped with maize, PP intercropped with sorghum, and PP intercropped with soybean. The experimental design used was a randomized block, with 4 replications (plots of 160 m²). Sward height, tiller density, dry mass production, and bulk density of total dry matter, of leaves, of stems, and of dead material were evaluated. The data were analyzed using the Tukey test at 5% probability. The total dry mass was higher in intercropping than in monoculture. Paiaguas palisadegrass intercropped with maize showed lower productions of total dry mass, leaf blade, and stems. The percentage of leaf blades was higher in Paiaguas palisadegrass intercropped in 2018 and in monoculture and intercropped with maize and soybean in 2019. Higher percentages of stems were registered in Paiaguas palisadegrass in monoculture in 2018 and in intercropping with sorghum in 2018 and 2019. In general, higher heights were found in Paiaguas palisadegrass in monoculture and smaller when intercropped with maize. The highest tiller densities were observed in Paiaguas palisadegrass in monoculture and the lowest in Paiaguas palisadegrass intercropped with maize and sorghum. Intercropping with agricultural crops reduces the production of Paiaguas palisadegrass. The accompanying agricultural crops alter the composition of the forage produced by the Paiaguas palisadegrass.

Keywords: Pasture establishments. *Glycine max*. Integrated systems. *Sorghum bicolor*. *Urochloa brizantha*. *Zea mays.*

Resumo
Objetivou-se avaliar características produtivas e estruturais do capim paiaguás implantado em monocultivo e em integração com culturas agrícolas em 2018 e 2019. Os tratamentos avaliados foram: capim paiaguás (CP) em monocultivo e CP integrado com milho, CP integrado com sorgo e CP integrado com soja. O delineamento experimental utilizado foi o de bloco ao acaso, com 4 repetições (parcelas de 160 m²). Foram avaliadas a altura, a densidade populacional de perfilhos, a produção de massa seca e densidade volumétrica da massa seca total, de folhas, colmos e material morto. Os dados foram analisados pelo teste de Tukey a 5% de probabilidade. A produção de massa seca total foi maior no cultivo integrado em relação ao monocultivo. O capim paiaguás em integração com milho apresentou menores produções de massa seca total, de lâmina foliar e de colmos. A porcentagem de lâminas foliares foi maior no capim paiaguás integrado em 2018 e em monocultivo e integrado com milho e soja em 2019. Maiores porcentagens de colmos foram registradas no capim paiaguás em monocultivo em 2018 e em integração com sorgo em 2018 e 2019. De maneira geral, maiores alturas foram encontradas no capim paiaguás em monocultivo e menores no integrado com o milho. As maiores densidades populacionais de perfilhos foram registradas no capim paiaguás em monocultivo e menores no capim paiaguás integrado com milho e sorgo. A integração com culturas agrícolas reduz a produção do capim paiaguás. A cultura agrícola acompanhante altera a composição da forragem produzida pelo capim paiaguás.
Palavras-chave: Estabelecimentos de pastagens. *Glycine max*. Sistemas integrados. *Sorghum bicolor*. *Urochloa brizantha*. *Zea mays.*

Introduction

Grasses from *Urochloa brizantha* (syn. *Brachiaria brizantha*) species have been vastly used in ruminant production due to their adaptation to diverse edaphoclimatic conditions in Brazil, their spread by seeds, their productivity, and their flexibility in the management[1]. Among the forage plants of *Urochloa brizantha*, the cultivar BRS Paiaguas (Paiaguas palisadegrass) is a new option for the establishment or renewal of pastures, presenting as characteristics higher productive potential in dry periods allied to good nutritional value[2]. For that, adequate management and establishment of this forage plant are needed.

For the establishment of pastures or agricultural crops, the integration between agriculture and livestock represents an advance in the sustainability of that activity, since it allies the aggregation of diverse income, rational use of the property, and reduction in production costs, minimizing the negative effects of crop-livestock production on the environment[3]. Additionally, the accompanying agricultural crop may be used to complement ruminant feeding, through silage or grains.

In integration, maize has been relevant due to its ease to cultivate and trade, possibility of selling it as grain, silage, or green maize. However, it is necessary to evaluate other options of agricultural crops which are less susceptible to extreme weather variability (short rainy periods and irregular rain distribution) and/ or may offer better profits. Thus, the cultivation of other crops such as sorghum (more adapted to hydric deficit) or soyabean (more profitable) may be an alternative in the production system, reducing risks, especially in atypical years.

In intercropped environments, there is an interspecific competition for light and nutrients that may modify the establishment of the used cultures(4). The competition for light may alter the rates of growth and development of the forage and thus its tillering dynamics, its sward structure(3), and its forage production(5). The competition for nutrients in the soil in intercropped environments also modifies the growth patterns of the plants, which may directly affect the success of the crop-livestock integration(3). This is particularly important for forage plants that grow under more competition for light and nutrients(3).

In this respect, some questions still need scientific answers such as: "does Paiaguas palisadegrass adequately develop in integrated systems?", and "does the accompanying crop affect the growth of Paiaguas palisadegrass?" This study was carried out regarding the following hypotheses: (i) the crop-livestock integrated system is adequate to the establishment of Paiaguas palisadegrass pastures and (ii) the accompanying agricultural crop affects the growth and the production of Paiaguas palisadegrass.

The aim of this study is, therefore, to give an account for the questions and hypotheses reported above. For that, the production of Paiaguas palisadegrass and its morphological components were evaluated when it was cultivated in monoculture and in intercropping.

Material and methods

This research was carried out in the experimental farm of the Federal University of Sergipe – UFS (Rural campus), located in São Cristóvão – Sergipe, (10º55'26" S; 37º11'49" W; 47 m altitude) from May 2018 to October 2019. This region is classified as tropical Aw, with rainy season from May to August and dry season from September to March. The average annual temperature of this region is 25.6 ºC, and the average rainfall is 1,409 mm. The weather information was obtained in the meteorological station, located at 500m from the experimental area (Figure 1) during the experiment.

The soil of the experimental area has sandy clay loam texture, being characterized as Argisol (6), with flat relief. Before the establishment of the experiment, in February 2018, samples of soil were taken at 0 to 20 cm deep in order to physically and chemically characterize the soil. The results revealed that the soil presented: 219.2 g/kg of clay; 106.6 g/kg of silt; 674.2 g/kg of sand; 4.10 pH in water; 0.46 cmolc/dm^3 of Ca^{2+}; 0.59 cmolc/dm^3 of Mg^{2+}; 0.88 cmolc/dm^3 of Al^{3+}; 3,09 cmolc/dm^3 of Al+H; cation-exchange capacity: 4.25 cmolc/dm^3 of cation-exchange capacity; 22.6 mg/dm^3 of K^+; 2.20 mg/dm^3 of P; 0.56 mg/dm^3 of Cu^+; 0.20 mg/dm^3 of Zn^+; 695.9 mg/dm^3 of Fe^{3+} and 10.1 g/dm^3 of organic matter. With those data, using the base saturation model(7), an acid correction of the soil was performed with 1.3 t/ha of calcarium in March 2018.

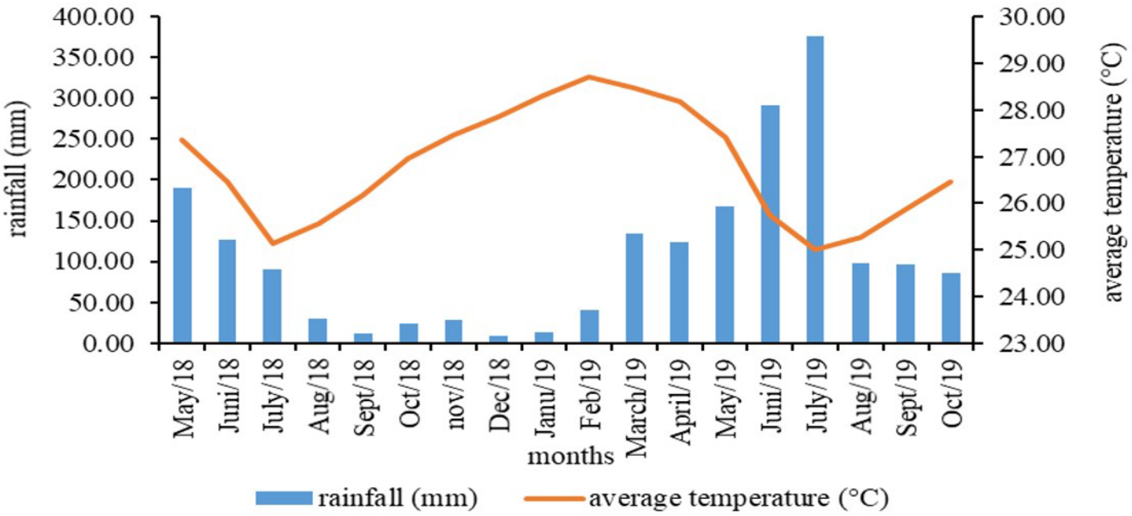

Figure 1. Rainfall and monthly average temperature from May 2018 to October 2019.

Paiaguas palisadegrass (*Urochloa brizantha* cv. BRS Paiaguas, syn. *Brachiaria brizantha* cv. BRS Paiaguas) was the evaluated plant, which was established in May 2018 and in May 2019. This forage was assessed in both monoculture and integration (consortium) with three agricultural crops: maize (*Zea may* cv. DKB 177 PRO 3), sorghum (*Sorghum bicolor* cv. BRS Ponta negra) and soybean (*Glycine max* cv. FTR 9130 iPRO). A complete randomized block design with four replications was used, achieving a total of 16 experimental units (plots of 160m^2).

In the beginning of May in 2018 (first year of cultivation) and of May in 2019 (second year of cultivation), the desiccation of the experimental area was performed. For that, 6 L/ha of glyphosate was mechanically applied[(8)]. 15 days after the desiccation, the sowing was performed using a no-till farming method. Paiaguas palisadegrass in monocultre and intercropped with maize were established with 0.70 m space between rows. The forage intercropped with sorghum and with soybean were established with 0.55 space between rows, following the recommendations for these crops[(9)]. A total of 7 kg/ha of pure viable seeds of Paiaguas palisadegrass was mixed with fertilizer on the planting day and both were deposited in the row of each crop with 0.06 in depth[(10)].

Bradyrhizobium japonicum bacteria were inserted into the soybean in both years. Before planting, the soybean seeds were humidified with a 10% (water + sugar) solution. This solution was applied in a ratio of 120 ml per 15 kg of seeds being completely homogenized. After this process, 100 g of peat inoculant to 15 kg of seeds, being well homogenized, was applied in order to guarantee 3.0 x 10^{-6} of viable cells/seed[(11)].

The foundation fertilization was performed with phosphorus and potassium in all of the treatments (in monoculture and intercropped). With the exception of the treatment with soybean (biological fixation), nitrogen was added to all the other treatments. The following fertilizers were used: 40 kg/ha of N in urea, 100 kg/ha of P_2O_5 in simple superphosphate, and 60 kg/ha of K_2O potassium chlorate[9]. They were mixed on the planting day. The cover fertilization with 100 kg/ha of N in urea was simultaneously performed in all the treatments except for the soybean. The application of the fertilizers was fractioned: 50 kg/ha when the fourth leaf of the intercropped plant was expanded and 50 kg/ha after the expansion of the sixth leaf of intercropped plant[9].

After the cultivation cycle of the agricultural crops (maize, sorghum, and soybean), they were harvested in October of each year. The evaluations of Paiaguas palisadegrass (in monoculture and intercropped) simultaneously occurred with the harvest of the intercropped plants.

The sward height of Paiaguas palisadegrass was measured at five randomly chosen points (disregarding 1.5 in the borders) in each experimental unit. At each point, the distance between the base of the plants (ground level) and their horizon was measured with a cm tape measure. The sward height corresponded to the mean of the five points per each experimental unit.

The production of dry matter of the forage was determined at two randomly chosen points (disregarding 1.5 m in the borders) per experimental unit. At each point, all the plants contained inside a 1 m^2 rebar frame were cut at ground level. After the cut, the forage was put in plastic bags, identified, and weighted. Next, two subsamples were taken. The first subsample was weighted and dried in a forced ventilation oven at 55ºC for 72 hours, then, it was weighted again. The second subsample was separated into leaf blades, stems, and dead material. Each component was placed in paper bags, identified and dried in a forced ventilation oven at 55ºC for 72 hours, then, they were weighted. These procedures enabled the estimation of total dry matter, leaf blades, stems, and dead material (kg/ha of DM), as well as their respective percentages.

The bulk density of the total dry matter (kg/ha.cm of DM) and of the morphological components were estimated by the division of the dry weight of each component by the height of the plants (cm) at cutting. The estimation of the relation leaf blade/stem was performed dividing the dry weight of the leaf blade and the dry weight of the stems. Tiller density was calculated counting all the plants inside the two 1 m^2 rebar frames. The frames were randomly placed in each plot (disregarding 1.5 m in each border).

The data of each cultivation year (2018-2019) were analyzed through variance analysis using the “F” test at 5% probability. Comparisons between the two years were not performed due to the climactic variability of each year. For the means that displayed differences (P<0.05), the Tukey’s test at 5% probability was used through SAS statistical package[12]. The statistical model used was $Y = m + a_i + b_j + e_{ijkr,}$ that is m = general mean of Y; a_i = agricultural crop effect; b_j = plot effect; e_{ijkr} = random error effect in each cultivation year.

Results and discussion

Sward height and tiller density of Paiaguas palisadegrass were affected by the cultivation system *(*P = 0.0047 and P < 00001 for the sward height, 2018 and 2019, respectively; P = 0.0003 and P < 0.0001 for tiller density*).* The planting of Paiaguas palisadegrass in monoculture resulted in high sward heights and tiller densities in both cultivation years (Figures 2A and B). Among the agricultural crops, the intercropping with maize resulted in a reduction of sward height, and the intercropping with either maize or sorghum decreased tiller density.

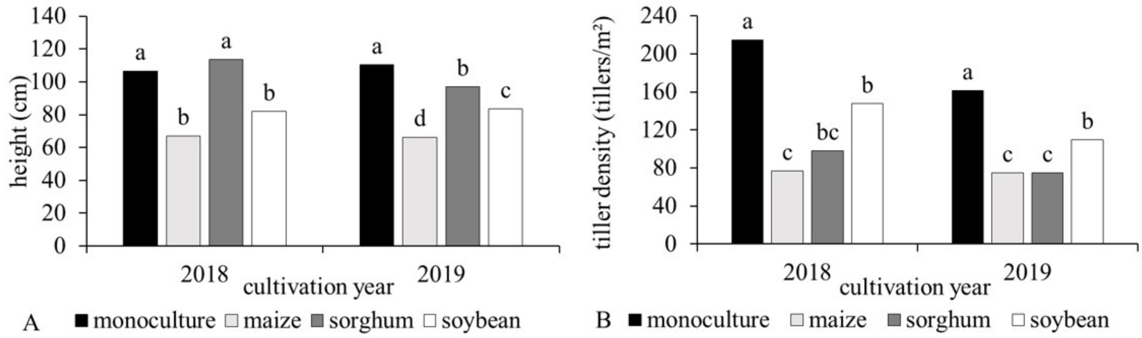

Figure 2. Sward height (A) and tiller density (B) of Paiaguas palisadegrass in monoculture and intercropped with maize, sorghum, and soybean. * For each cultivation year, means followed by the same lower-case letter do not differ between them (P>0.05) by Tukey's test.

The absence of an agricultural crop enabled the growth of Paiaguas palisadegrass in an environment with greater light intensity, which favored the growth of its height and of its tiller set. Under this condition, Paiaguas palisadegrass probably absorbed light in greater quantity and quality, which favored its growth rates(13,14). According to3), the competition for light in crop-livestock integrated systems are high because in most cases, the agricultural crops were genetically enhanced to be more responsive to management practices. This may also make the initial growth of Paiaguas palisadegrass difficult.

The accompanying crop also affected the sward height and the tiller density of Paiaguas palisadegrass. On average, the swards reached 211 cm for maize, 260 cm for sorghum, and 69 cm for soybean, with a stand of 70 thousand plants/ha for maize, 140 thousand plants/ha for sorghum, and 280 thousand plants for soybean. Therefore, maize and sorghum probably favored higher intraspecific competition for light since they presented higher sward heights and also for being C4 plants, resulting in a greater growth rate in comparison to C3 soybean(15).

The productions of total dry matter (P = 0.0001 and P = 0.0001, 2018 and 2019), of leaf blades (P = 0.0026 and P < 0.0001, 2018 and 2019, respectively), of stems (P = 0.0001 and P < 0.0001, 2018 and 2019, respectively), and of dead material (P = 0.0010 and P = 0.0320, 2018 and 2019, respectively) were affected by the cultivation system. In 2018 and 2019, the productions of total dry matter (Figure 3 A), of leaf blades (Figure 3 B), of stems (Figure 3 C), and of dead material (Figure 3 D) in monoculture were higher than in the integrated system. In the integrated system, Paiaguas palisadegrass intercropped with maize presented lower total dry mass with higher participation of dry matter of dead material. On the other hand, when intercropped with sorghum, Paiaguas palisadegrass presented higher production of total dry mass mostly in 2019, due to the higher production of leaf blades and, above all, of stems.

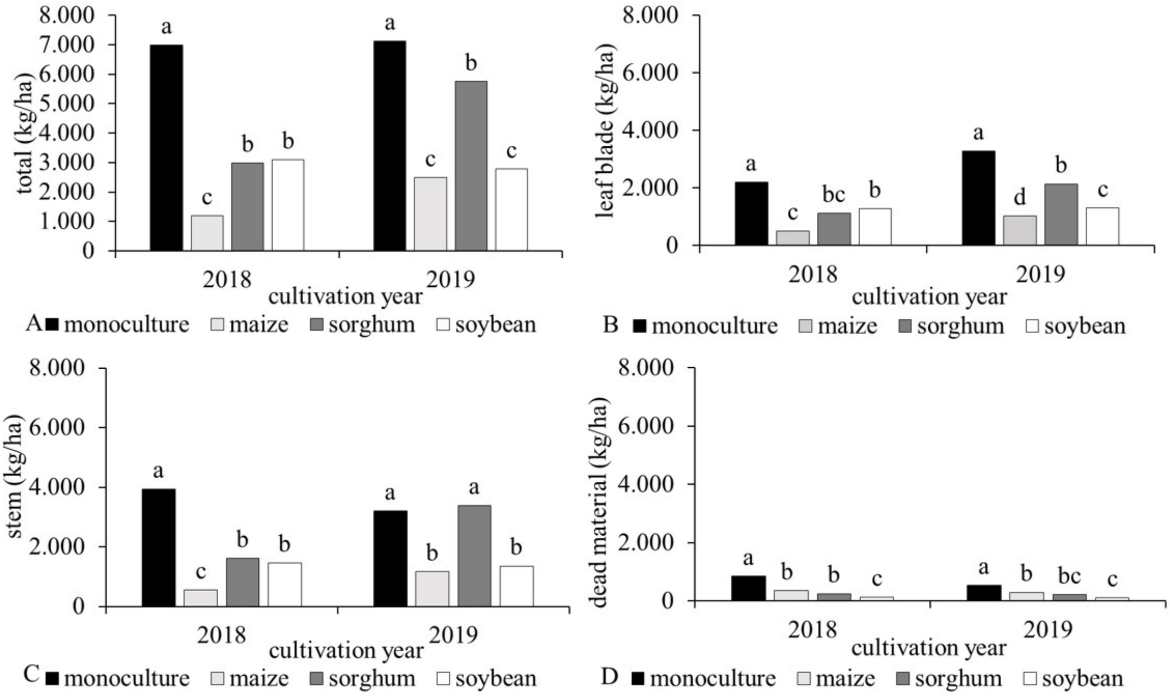

Figure 3. Total dry mass (A), of leaf blade (B), of stem (C), and of dead material (D) of Paiaguas palisadegrass in monoculture and intercropped with maize, sorghum, and soybean. *For each cultivation year, means followed by the same lower-case letter do not differ between them (P>0.05) though Tukey's test.

It was possible to verify that the absence of interspecific competition for light at establishment benefited the production of total dry mass of Paiaguas palisadegrass. This higher production of total dry mass is a consequence of higher plants (Figure 2 A) and of a community of plants with higher quantities of tillers (Figure 2 B). As the plants were growing without the accompanying crops reaching a height of 110 cm, there was certainly an increase of intraspecific competition for light. Higher plants present higher leaf area index, and, consequently, higher light interception[5]. After reaching 95% of light interception, which for *Brachiaria brizantha* varies from 25 to 35 cm, in well managed swards[16-18], the accumulation of stems and dead material increases [5], which may be observed in Figures 3 C and 3 D.

Conversely, the intercropping reduced the production of dry mass of Paiaguas palisadegrass (Figure 3 A). The higher interspecific competition with agricultural crops may be the reason for the reduction of the production of biomass of the forage, since it reduces the available light, which lowers the rates of photosynthesis, and, consequently, of the production of dry mass[5]. Undoubtedly, in integrated systems, there is a tendency of reduction in the forage production in relation to monoculture systems[3, 19, 20].

Once more, it is possible to observe that the accompanying agricultural crop has an effect not only on the production of total dry mass of Paiaguas palisadegrass, but also on its morphological components. A higher production of total dry mass is noted when Paiaguas palisadegrass is intercropped with sorghum in comparison when intercropped with maize (Figure 3 A) due to higher productions of dry mass, leaf blades, and stems, and lower of dry mass of dead material. This pattern indicates that the forage under lower light condition alters its growth habit when in competition[20]. It is worth noting, however, that: (i) lower forage production may be temporary, being reestablished after the harvest of the agricultural crops; certainly[3], when evaluating *Brachiaria decumbens* intercropped with maize and sorghum, registered higher rates of growth, and, consequently, of forage production in the swards established in intercropping after the harvest of the agricultural crops; (ii) any initial reduction in forage production in integrated systems will be compensated for the harvest of the grains. Certainly, in 2018 and 2019, respectively, the intercropping enabled the production of 5,716 and 6,152 kg/ha grains of maize, 3,51 and 6,150 kg/ha grains of sorghum, and 2,967 grains of soybean. This production is inexistent for animal breeders that choose to establish Paiaguas palisadegrass in monoculture.

The percentages of leaf blades ($P = 0.0269$ and $P = 0.0073$, in 2018 and 2019, respectively), of stems ($P = 0.0415$ and $P = 0.0100$, in 2018 and 2019, respectively), dead material ($P = 0.0061$, in 2019) and the relation leaf blade/stem ($P = 0.0219$ and $P = 0.0047$, in 2018 and 2019, respectively) were influenced by the cultivation systems. In 2018, Paiaguas palisadegrass in monoculture presented lower percentage of leaf blade (Figure 4 A) and higher percentage of stems (Figure 4 B), which resulted in a low leaf blade/stem relation (Figure 4 D) in relation to the intercropped one. In 2019, Paiaguas palisadegrass in monoculture presented an inverse pattern, with high percentage of leaf blade, lower percentage of stems, and higher leaf blade/stem relation. In the integrated system, Paiaguas palisadegrass intercropped with sorghum presented lower percentage of leaf blade, higher percentage of stems, and low leaf blade/stems relation.

Although Paiaguas palisadegrass in monoculture presented similar production of total dry mass (Figure 3 A) between 2018 and 2019, its morphological composition was distinct (Figure 4 A, B, C, and D). In 2019, the percentage of leaf blades was 49.7% higher (47.6 versus 31.8%), the percentage of stems was 19.8% inferior (56.0 versus 44.9%), and the leaf blade/stem relation was 87.7% superior (0.57 versus 1.07) in comparison to 2018. This happens because the growth of forage is directly linked to the edaphoclimatic conditions (rainfall, luminosity, temperature, soil fertility, physical characteristics, among others)[5,13], which were different in each year (Figure 1), and may also determine variations in the growth of the forage[21].

Among the agricultural crops, Paiaguas palisadegrass intercropped with sorghum reached high sward height (Figure 2 A), low tiller density (Figure 2 B), and high production of dry mass of stems (Figure 3 C) and percentage of stems (Figure 4 B), which resulted in a reduction of leaf blade/stem (Figure 4 D). As discussed previously, higher sorghum plants (260 cm), associated with the stand with 140 thousand plants/ha probably increased the competition for light for Paiaguas palisadegrass. Higher competition for light reduces the quantity and quality of light that penetrates the forage sward[12, 13, 16]. Under conditions of high competition for light, excessive shading of the sward triggers a senescence process and tissue death, reducing the percentage of leaves. Concomitantly, a process of elongation of stems is triggered, increasing the percentage of stems[5,13]. This is a consequence of etiolation (elongation of internodes) as an adaptation of the grass when attempting to reach a fast growth in extension in order to increase the chances to grow above the sward when shaded[14].

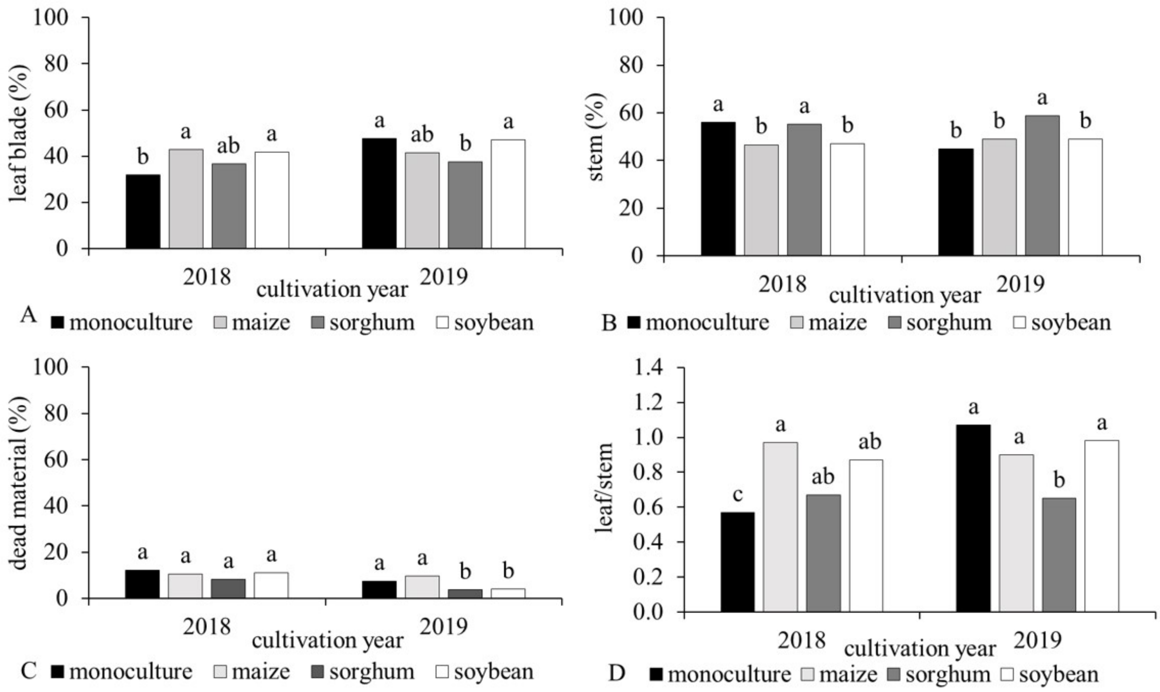

Figure 4. Percentages of leaf blade (A), of stem (B), and of dead material (C), and leaf blade/stem relation (D) of Paiaguas palisadegrass in monoculture and intercropped with maize, sorghum, and soybean. * For each cultivation year, means followed by the same lower-case letter do not differ between them (P>0.05) by Tukey's test.

The bulk density of the total dry mass (P = 0.0001 and P < 0.0001, in 2018 and 2019, respectively), of leaf blade (P = 0.0046 and P < 0.0001, in 2018 and 2019, respectively), of stems (P = 0.0001 and P = 0.0001, in 2018 and 2019, respectively), and of dead material (P = 0.0021 and P = 0.0054, in 2018 and 2019, respectively) was altered by the cultivation system. For all the evaluated variables, Paiaguas palisadegrass in monoculture presented higher values (Figure 5 A, B, C, and D). In integrated systems, Paiguas palisadegrass intercropped with sorghum presented high bulk density of total dry mass (Figure 5 A), composed by a high bulk density of stems (5 C), while in intercropping with maize, it presented lower values of *bulk density of total dry mass.*

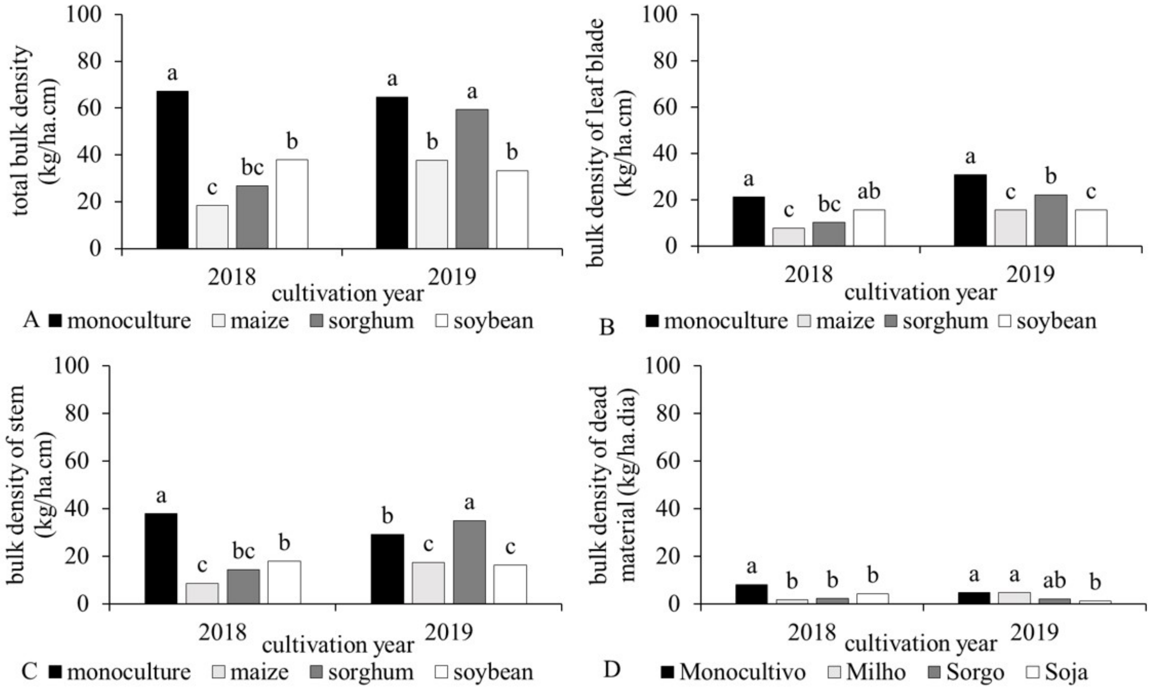

Figure 5. Bulk density of total dry mass (A), of leaf blade (B), of stem (C), and of dead material (D) of Paiaguas palisadegrass in monoculture and intercropped with maize, sorghum, and soybean. * For each cultivation year, means followed by the same lower-case letter do not differ between them (P>0.05) by Tukey's test.

The higher bulk density of total dry mass of Paiaguas palisadegrass in monoculture (Figure 5A) is consistent with its higher production of total dry mass (Figure 3 A). Conversely, the bulk density of the total dry mass of Paiaguas palisadegrass intercropped with maize was lower in both cultivation years. This reduction is probably related to the spatial arrangement of maize leaves[22] that improves its light interception due to its genetic enhancement, decreasing the quantity and quality of light that reaches the inferior portions of forage sward, where the forage plants stay, reducing the bulk density of the total dry mass of Paiaguas palisadegrass (Figure 5A). As Paiaguas palisadegrass was established in the same cultivation row of the agricultural crop, the light interception sharply decreases for the forage.

In relation to the first hypothesis "the crop-livestock integrated system is adequate to the establishment of Paiaguas palisadegrass pastures", it was verified that the intercropping reduced the growth and production of Paiaguas palisadegrass. Possibly, this production will normalize after the harvest of the agricultural crops. Nevertheless, the animal breeder should be aware that there will be an increase in the amount of time between Paiguas palisadegrass sowing and its use by animals in integrated systems in comparison to monoculture. On the other hand, intercropping with agricultural crops provides a production of grains that may be traded or used in animal feeding. The tested hypothesis must be accepted.

The second hypothesis “the accompanying agricultural crops affect the growth and the production of Paiaguas palisadegrass” must also be accepted. The choice of the accompanying agricultural crop may be done according to the objectives of the farmer, aiming at increasing profits, improving trade, reducing risks, or producing supplementary food for ruminants. However, depending on the chosen agricultural crop, the production of Paiaguas palisadegrass may be highly or minimally affected.

Conclusions

The intercropping with agricultural crops reduces the production of Paiaguas palisadegrass. The accompanying agricultural crop alters the composition of the forage produced by Paiaguas palisadegrass.

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Conflict of interest

The authors declare the inexistence of conflict of interest.

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