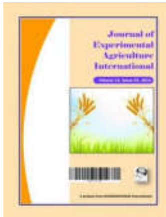

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# Production of Maize Silage is Possible in Integrated Systems with Arboreal Component

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***Authors' contributions***

*This work was carried out in collaboration among all authors. Author RAC designed the study, performed the statistical analysis, wrote the protocol and wrote the manuscript. Authors EBCS, AJC and LFG managed the field and laboratory works and wrote the first draft of manuscript, Author JGA give support in the analyses of the study and supported the writing of manuscript. Author CDG managed the literature searches and help in the statistical analyses. Authors WMP, LDSH and JAR supported the writing and English translation. All authors read and approved the final manuscript.*

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## ABSTRACT

Distribution of the intercropped plants determines the production but it is highly dependent on the machinery of the property. Producers, who harvest silage row by row, depend on plantings with greater spacing. This study was aimed to evaluate the maize intercropped for cultivated silage in 0.90 m between rows, with grass under the shade and full sunlight conditions. Maize with brachiaria grass was tested in four sowing densities (0, 2, 4 and 6 kg of pure and viable seeds per hectare). The factorial treatments (2x2x4) were distributed in a split-plot design with four repetitions. The maize agronomic characteristics and the silage quality were evaluated. There was a high level of competition when associated with maize, piatã and eucalyptus. Aggressive piatã grass growth, with

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light restriction by trees, have affected strongly the maize forage mass-produced, and consequently, reduced silage production. Regarding grain yield, the intercrop with ruziziensis grass was superior (210%) to the intercrop with piatã grass. It was mainly influenced by the low yield in the piatã grass intercropped under shade conditions. This pattern was different for ruziziensis because it was a less aggressive grass in terms of growth. For plantations with 0.90 m of spacing, there was a light restriction. The maize intercropped under the shade of trees must be done with lower growth rate grass to reduce competition and maintain the yield.

*Keywords: Brachiaria grass; intercropped; row spacing; shadowing; eucalyptus.*

## 1. INTRODUCTION

Integrated systems are modes of production that involve agriculture, livestock and trees in the same environment. The association of the components brings several benefits namely, improved soil fertility, root system, water and nutrient cycling, greenhouse gas mitigation and production diversification. Despite the benefits, it is necessary to define a break-even point in which all cultures can develop adequately to remain productive. Thus, different arrangements must be tested in different regions, aiming to identify parameters for the efficient use of the integration. Among the most used crops, maize stands out for its versatility and ease of cultivation.

The maize crop stands for its high yield of dry matter, nutritive value and flexibility of use, being one of the main crops in Brazil. An important use of the maize crop is for silage production, aiming the massive supplementation of the herd in the time of pasture shortage. Although many studies have shown the benefits of planting with smaller row spacings [1], there are high proportion of producers who harvest the crops row by row, which makes the smallest spacings impractical because of machinery.

Based on this assumption, the adjustment of the other cultures when in integrated systems is fundamental. Listing the main cultural aspects of integration is of the utmost importance to strengthen the adoption of these systems [2]. Productive components should be allocated to sustain the production, to use the growth capabilities of each component with less competition among themselves and with maximum efficiency [3].

The use of conservation techniques aiming at production and minimal degradation of natural resources, such as the no-till system, had been the best route for ecological intensification [4].

The area planted with the no-tillage system has increased rapidly, corresponding to 50% of the area planted with grain crops [5]. The adoption of no-till improves the sustainability of agricultural activities, but gains are limited by the lack of crop rotation and soil cover [6]. The *Brachiaria* grass sowing can be done in several ways, however, simultaneous sowing with maize has been recommended due to greater efficiency and economy [7].

Migrate from specialized systems to mixed systems, more complex, demand greater managerial capacity, specialized teams and more investments in infrastructure [8]. Integration, since it involves different cultures in a simultaneous productive cycle, has been introduced slowly. The possibility of maximizing soil used for the three distinct activities and with economic return in the short, medium and long term is one of the motivating factors for the implementation of the integrated systems in several rural properties.

However, there is little cultural information in integrated production systems, especially when the maize and grass are associated with the forest components [2].

This research was aimed to evaluate the maize and grass production and bromatological composition of maize for silage production intercropped with ruziziensis and piatã grasses submitted to different sowing rates associated with shade conditions and full sun in the Brazilian Cerrado.

## 2. MATERIALS AND METHODS

The experiment was carried out at Experimental Base of Integrated Milk Production Systems of the Brazilian Agricultural Research Corporation (Embrapa Agrossilvipastoril), in the municipality of Sinop – MT, Brazil, latitude 11° 51’ 43” South, longitude 55° 35’ 27” West and 384 m altitude. The experimental area is situated on a red-yellow Latosol in flat relief. The climate of the region is Aw (tropical climate with dry season) according to Köppen classification.

The experimental design was a randomized split-split plot, using a 4x2x2 factorial arrangement, with four seeding densities of the grass (0, 2, 4 and 6 kg of pure and viable seeds ha$^{-1}$), two forages (ruziziensis and piatã) and two conditions of luminosity (shade and full sun), total 16 treatments with four repetitions.

The experimental base was composed of four quadrants subdivided in treatments of shade and full sun with 10 hectares each where the cultures were rotating. The shading was provided by the presence of Eucalyptus (*Eucalyptus urograndis* H-13 clone), with four triple tree row every 15 m in spacing 3 x 2 m to promote rapid shading of the tree. At the implantation of the experiment, the trees were 23 months and approximately 10 m high.

Maize sowing was performed with 0.90 m line spacing to simulate mechanized harvest row by row, however for the experiment, the harvest was done manually. It was carried out by planning a stand of 60,000 plants ha$^{-1}$.

The hybrid used was Herculex I, transgenic to caterpillar due to the great pest pressure that occurs in Mato Grosso in the harvest period. The sowing was done with fertilizer sowing and the plots were divided and staked after sowing of maize.

The seeds of the grasses presented 50% of cultural value. The sowing was done manually every 0.45 m between the furrows, regardless of the maize spacing being 0.90 m.

In the fertilization of the maize sowing, was applied 350 kg ha$^{-1}$ of the formulated fertilizer 04-30-16. For the establishment fertilization, 500 kg ha$^{-1}$ of the 20-00-20 formulation in the cover, was applied 30 days after sowing, when the maize plants were in the phenological stage of six fully developed leaves.

Post-emergence dicotyledonous weed control was performed 16 days after emergence (DAE), with the herbicide atrazine at the dose of 1000 g ha$^{-1}$ of the active ingredient. The application was carried out using a tratorized bar sprayer, adjusted to the system, equipped with fan nozzles and regulated to apply 200 L ha$^{-1}$ of syrup.

Each plot measures 86.4 m$^2$, with the central rows being discounted from the borders. The maize harvesting point was monitored, starting when maize presented 33 to 35% dry matter.

At the time of harvest, the booth was counted, the plants being harvested, grouped and weighed to determine the green mass production (GMP) per hectare. The plant height (m) and insertion of the ear height (m) were determined with a graduated ruler, stem diameter (mm) was determined with digital pachymeter and the green leaves number with the total leaves number were determined, determining the stay green of all plants collected for production. Three plants were sampled to evaluate the morphological composition of maize. The plants were separated into dry leaves, green leaves, stems, bracts and ear of corn. After drying, the corn ears were separated from grain and cob and then was weighed. The samples were dried in a forced-air circulation oven at 65ºC for 72 hours. The dry mass (DM) yield of maize was obtained by weighing the plants harvested within the useful area of each plot and extrapolated to the hectare. The plants were harvested in all the rows sown, being collected the plants in 1 m per row, a total of 14 m of rows per plot. The living area ensured that the shade effect was portrayed throughout the plot.

**Table 1. Results of the soil chemical and physical characteristics in the experimental area at Embrapa Agrossilvipastoril, Sinop – MT, Brazil**

| **Chemical Characteristics** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **[1]pH** | **[2]P** | **[3]K** | **[4]Ca+Mg** | **[5]Ca** | **[6]Mg** | **[7]Al** | **[8]H** | **[9]OM** | **[10]S** | **[11]CEC** | **[12]V** |
| **$H_2O$** | **mg dm$^{-3}$** | | **cmol$_c$ dm$^{-3}$** | | | | | **g dm$^{-3}$** | **cmol$_c$ dm$^{-3}$** | | **%** |
| 5.7 | 6.2 | 55 | 2.5 | 2.0 | 0.5 | 0.2 | 3.5 | 24.8 | 2.7 | 6.3 | 42.1 |
| **Physical Characteristics** | | | | | | | | | | | |
| **Sand** | | | | **Silt** | | | | **Clay** | | | |
| g kg$^{-1}$ | | | | | | | | | | | |
| 266 | | | | 134 | | | | 601 | | | |

*[1]Potential of Hydrogen; [2]Phosphorus; [3]Potassium; [4]Calcium+Magnesium; [5]Calcium; [6]Magnesium; [7]Aluminium; [8]Hydrogen; [9]Organic Matter; [10]Sulfur; [11]Cation Exchange Capacity; [12]Base saturation*

The yield of the grasses in kg of DM per hectare was determined, being collected 2 m of the row in each plot. The samples were placed in an air circulating oven at 55ºC for 72 hours. The total dry mass production was obtained by adding the mass yield of maize and grasses. The production of the different components of the plant was calculated as a function of the proportion generated by the weighings multiplied by the dry mass of the maize and expressed in kg DM $ha^{-1}$. The monitoring of the light to determine the level of shading was carried out with the LI-250 device of the LICOR.

The forage collected in the row was ground, homogenized and stored in mini silos. After the 45 days of the incubation period, the material was removed from each silo, oven-dried at 55ºC to obtain constant mass, ground in Willey mills with a 1 mm sieve, followed by the bromatological analyzes. Analyzes of pH and titratable acidity were performed.

The contents of neutral detergent insoluble fiber (NDF), acid (ADF) and lignin were determined according to the methodologies by Van Soest et al. [9], using Ankon (Ankon 200 Fiber Analyser Technology Corporation) equipment, being added sodium sulphite in order to solubilize the protein adhered to the cell wall [10] and the thermostable alpha-amylase enzyme for solubilizing the starch [9]. The lignin was analyzed with the addition of 72% sulfuric acid in the insoluble residue of the ADF determination [9]. *In vitro* dry matter digestibility (IVDMD) analyzes and organic matter (IVOMD) were performed with Daisy Incubator II (Ankon). The total nitrogen was determined by dry combustion of the sample at 1400ºC using the CHNS elemental analysis method [11] on the automatic element analyzer Macrocube (Elementar, Germany).

The data were analyzed using the MIXED procedure of SAS 9.2, and the comparison of the mean was performed by the PDIFF test at 5% significance after analysis of variance.

## 3. RESULTS AND DISCUSSION

Although the height of the maize plants was higher in the shade (10%) ($P < .0001$), there was a significant effect of the intercropped species on this maize variable. In the intercrop with ruziziensis grass, maize plants grew more in the shade (2.11 m) relative to the full sun (1.82 m), while intercropped with piatã grass, this behaviour was inversely, that is, in the shade, maize plants were lower (1.91 m) than full sun (2.01 m) ($P < .0001$) ( Table 2).

When comparing the cultivation under the shade and full sun, shading was expected to modify the leaf architecture of the plants as a whole, presenting an increase of canopy area and plant height according to the increase of the shade level. This would be a typical response of species under low light conditions, which would compensate for the light limitation with an increase of the catchment area [12]. The same response pattern of ruziziensis grass was also described for maize shaded with eucalyptus, where the more shaded the higher maize the plant presented [13].

However, stem diameter decreased as light restriction occurred. The intercrop with ruziziensis grass provided finer maize plants (5%) in the shade (15.6 mm) concerning the full sun (16.3 mm) ($P < .0001$), while this difference was greater for the intercrop with piatã grass (24%) (Table 2). There was a large reduction of stem diameter, from 17.6 mm in full sun to 13.4 mm in shading condition. Competition for growth factors in denser crops might lead to lower accumulation of a dry mass of maize and, consequently, thinner stems [14]. This information combined with the height of maize plants indicates that maize was losing competition when associated with a more aggressive growth forage (piatã grass) when it was still influenced by tree shade. Due to this aggressiveness, of the piatã grass, it was observed that there were no changes in stem diameter up to 4 kg of PVS $ha^{-1}$ of grass seeds (15.6 mm), but with 6 kg of PVS $ha^{-1}$ seed, there was a reduction of stem diameter (14.9 mm). For ruziziensis grass, maximum stem diameter was reached with 4 kg of PVS $ha^{-1}$ of grass seed (16.7 mm) ($P = .0233$) (Table 2). According to Busato and Busato [15], stem diameter is more affected by intense competition than the height of the maize plant.

Regarding ear insertion height, it was verified that taller plants had higher ear height. The intercrop with ruziziensis showed maize plants with ear 30% higher in the shade (1.11 m) in relation to the full sun (0.86 m), while in intercrop with piatã grass, the ears were 8 % higher (0.93 m) relative to the full sun (1.02 m) ($P <0.0001$) (Table 2).

An indicative that reinforces the high level of competition between plants damaging the maize in the condition of shade with piatã grass was the low green leaves number (6 leaves) while the other treatments maintained from 8 to 10 green leaves per plant (P =.0512) (Table 2). Consequently, the number of dry leaves and the stay-green were lower for maize plants intercropped with piatã grass (20%) than with ruziziensis grass (P<.0050). The green leaves number in the maize plant showed to be very sensitive to competition also in the experiments carried out by Busato and Busato [15].

The intercrop with ruziziensis grass in the shade provided a greater survival of maize plants (47,000 plants) (P =.0002) (Table 2), probably due to lower effects of competition. The plant population presented a correlation of 50% with height, that is, other factors influenced the height of plants such as the environment or interspecific competition. According to Borghi and Crusciol [16], the intercropping of maize with the brachiaria in the row and

**Table 2. Agronomic characteristics of maize intercropped with *Brachiaria* grasses under shading and full sunlight conditions**

| Maize Plant Height (m) | Full Sun | Shade | Mean |
|---|---|---|---|
| Maize/Ruziziensis | 1.82 Bb | 2.11 aA | 1.97 |
| Maize/Piatã | 2.01 aA | 1.91 bB | 1.96 |
| Mean | 1.92 b | 2.01 a | |
| **Stem Diameter (mm)** | | | |
| Maize/Ruziziensis | 16.3 aB | 15.6 bA | 16.0 A |
| Maize/Piatã | 17.6 aA | 13.4 bB | 15.5 B |
| Mean | 17.0 a | 14.5 b | |
| **Ear Insertion Height (m)** | | | |
| Maize/Ruziziensis | 0.86 bB | 1.11 aA | 0.99 |
| Maize/Piatã | 1.02 aA | 0.93 bB | 1.98 |
| Mean | 0.98 b | 1.02 a | |
| **Green Leaves Number (unit)** | | | |
| Maize/Ruziziensis | 10.1 aA | 9.5 aA | 9.8 A |
| Maize/Piatã | 7.6 aB | 6.0 bB | 6.8 B |
| Mean | 8.9 a | 7.7 b | |
| **Plant Population (plants ha$^{-1}$)** | | | |
| Maize/Ruziziensis | 41,643 bA | 46,930 aA | 44,286 A |
| Maize/Piatã | 40,078 aA | 39,323 aB | 39,700 B |
| Mean | 40,861 b | 43,126 a | |

*Means followed by the same letter, uppercase in the row and lowercase in the column, do not differ statistically between them by the PDIFF test (P >0.005)*

**Table 3. Yield characteristics of maize intercropped with *Brachiaria* grasses under shading and full sunlight**

| Grain Yield (kg ha$^{-1}$) | Full Sun | Shade | Mean |
|---|---|---|---|
| Maize/Ruziziensis | 8,000 bA | 9,300 aA | 8,650 A |
| Maize/Piatã | 6,060 aB | 2,350 bB | 4,200 B |
| Mean | 7,030 a | 5,830 b | |
| **Grass Dry Mass (kg ha$^{-1}$)** | | | |
| Maize/Ruziziensis | 1,350 aB | 575 bB | 960 B |
| Maize/Piatã | 1,700 aA | 1,710 aB | 1,705 A |
| Mean | 1,525 a | 1,140 b | |
| **Maize Dry Mass (kg ha$^{-1}$)** | | | |
| Maize/Ruziziensis | , 006 Ab | 12,240 Aa | 10,123 A |
| Maize/Piatã | 9,303 Aa | 5,949 Bb | 7,626 B |
| Mean | 8,655 | 9,095 | |
| **Maize Total Mass (kg ha$^{-1}$)** | | | |
| Maize/Ruziziensis | 9,358 aB | 9,879 aA | 9,618 B |
| Maize/Piatã | 13,943 aA | 7,656 bB | 10,800 A |
| Mean | 11,653 a | 8,767 b | |

*Means followed by the same letter, uppercase in the row and lowercase in the column, do not differ statistically between them by the PDIFF test (P > .0050)* between row provided a smaller plant stand in both spacings (0.45 and 0.90 m) as well as the intercrop in the row in the spacing of 0.45 m, probably due to the greater competition between species during the initial development of maize.

Regarding grain yield, the intercrop with ruziziensis grass was superior (210%) to the intercrop with piatã grass (Table 3). This mean was influenced mainly by the low yield in the piatã grass intercrop under shade conditions. [17] had a negative effect of the increase in sowing density of brachiaria on grain yield maize, an effect not verified in the present experiment (P>.05), which corroborated with the results of [18].

Another significant difference in response to shading was the sensitivity of forage species to shading. The piatã grass did not present any type of interference in its accumulation of DM due to the shade, but the ruziziensis grass had its yield affected drastically (Table 3).

Even with the change in DM production of grass, the maize intercrop with ruziziensis showed the same total forage yield when harvested at the silage point. The more drastic competition suffered by maize intercrop with piatã grass and trees caused the total production to be reduced (45%) (Table 3). Although total dry mass yield in the sun was higher than in the shade, this response was true only for the most productive (piatã grass). On the other hand, ruziziensis grass presented a lower growth potential, reducing the cumulative effect of competition. The mean yield of total dry mass (maize + grass) in a system intercropped with *Uroclhoa brizantha* was 14 ton ha$^{-1}$, while in monoculture it was 12 ton ha$^{-1}$ [19].

As for sowing density, the values of total DM production were increasing and positive the higher the sowing density of ruziziensis grass, thus increasing the mass of grass and maize (Fig. 1). For the intercrop with piatã grass, the highest yields were obtained with the rates of 2 to 4 kg of PVS ha$^{-1}$, with 0 and 6 kg ha$^{-1}$ being the lowest yields due to no mass aggregation by the grass or when no had grass, by high competition at the highest rate.

The differences obtained in maize yield (Table 3) highlight the effect of shade on forage mass yield to be ensiled, mainly with the piatã grass that presented mean total dry mass yield of 13.94 ton ha$^{-1}$ in full sun and 7.65 ton ha$^{-1}$ in the shade [19].

The mean pH of the ensiled material was 3.69 (Table 4) in silage composition and it was considered satisfactory in terms of fermentation standard [20] since there was an efficient fall from a forage mass with pH of 5.5 before ensiling.

The titratable acidity is considered as a more appropriate concept to judge the fermentation, being more important than the pH itself [21]. The determination of the titratable acidity has a high correlation with the lactic acid content of the silage, which only with the pH of the silage is not properly related [22]. There was no effect of the treatments on the titratable acidity of the silages produced, obtaining the mean of 20.13 being considered adequate [23].

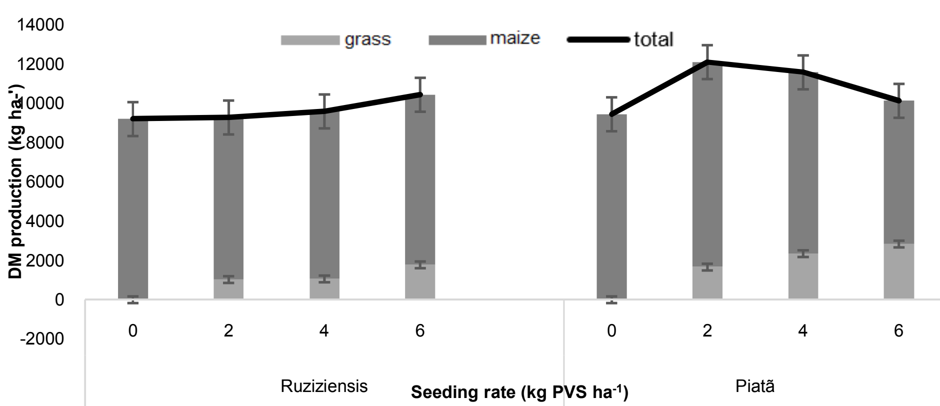


**Fig. 1. Total and compartmentalized dry matter production of maize for silage under sowing rate of Ruziziensis and Piatã grasses**

**Table 4. Nutritive value of Maize Silage intercropped with Brachiaria under shading and full sunlight conditions**

| **Neutral Detergent Fiber (%)** | **Full Sun** | **Shade** | **Mean** |
|---|---|---|---|
| Maize/Ruziziensis | 42.06 aA | 41.75 aA | 41.90 A |
| Maize/Piatã | 37.77 aA | 43.19 aA | 40.48 B |
| Mean | 39.91 b | 42.47 a | |
| ***In Vitro* Dry Matter Digestibility (%)** | | | |
| Maize/Ruziziensis | 72.95 aA | 72.35 aA | 72.65 A |
| Maize/Piatã | 73.22 aA | 68.71 bB | 70.96 B |
| Mean | 73.08 a | 70.53 b | |
| Lignin (%) | 1.96 b | 2.20 a | |
| Acid Detergent Fiber (%) | 21.65 b | 23.10 a | |
| pH | 3.67 b | 3.71 a | |

*Means followed by the same letter, uppercase in the row and lowercase in the column, do not differ statistically between them by the PDIFF test (P >.005)*

There was a small increase in the NDF content (Table 4) when the maize intercropped with the piatã grass was produced in the shade (43.2%) with the full sun (37.8%) (P=.0021). For the intercrop with ruziziensis grass, the NDF content was unchanged (41,9%). Despite this small variation, it is observed that the NDF content of this experiment was close to those found in the literature (41%), on mean, in an experiment with eleven maize cultivars at four sites for three years [24].

There was a small increase in the ADF content (Table 4) when maize was produced in the shade (23.1%) to full sun (21.7%) (P=.0355). Nevertheless, the ADF contents were below those cited in the literature as satisfactory values for maize silage of 24 to 28% [24].

The lignin content in the silage mass did not change (Table 4), being very low (2.08%) and lower than those reported in the literature (3-4%) [24]. Thus, the fibre quality of this silage can be considered high because the most digestible portion (hemicellulose) is higher due to the low levels of ADF. This confirmation is made utilizing the high values of *in vitro* dry matter digestibility (71.80%, on mean), while in the above-mentioned silages, the mean digestibility obtained was 60 % [24].

However, the higher fibre content in the maize, piatã grass and tree integrated provide a slight reduction in silage digestibility (68.7%) (Table 4) to the full sun integration (73.2%) (P = .0002). The maize intercropped with ruziziensis grass did not affect the digestibility of silage. According to [25], maize silage produced with xaraés grass ensures higher yield, however, with ruziziensis grass, silage presented better bromatological composition with lower fibre, crude protein, total digestible nutrients, and higher dry matter digestibility.

There were no significant variations in mineral content (3.2%) despite some statistical differences. The crude protein content was 8%, on mean, being lower content in the silage with piatã grass, probably because there is a greater proportion of grass in the mass. The maize silage of the intercrop with ruziziensis grass had a CP content of 8.3% and 7.6% in the intercrop with piatã grass (P<.0001). Also considered adequate when comparing the silages used as reference (6 to 7% CP) [23].

## 4. CONCLUSION

The production of maize silage with high participation of grains in the mass and of quality is possible in integrated systems, as long as the level of competition between the plants is controlled.

When sowing is carried out in shaded environments, preference must be given to grasses with slower growth or lower sowing rates.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

## REFERENCES

1. Demétrio CS, Fornasieri Filho D, Cazetta JO, Cazetta DA. Performance of maize hybrids submitted to different row spacing and population densities. Brazilian Journal of Agricultural Research. 2008;43(12): 1691-1697.

Available:http://www.scielo.br/pdf/pab/v43n12/v43n12a08.pdf . Portuguese

2. Balbino LC, Cordeiro LAM, Porfírio da Silva V, Moraes A, Martinez GB, Alvarenga RC, Kichel NA, Fontaneli RS, Santos HP, Franchini JC, Galerani PR. Technological evolution and productive arrangements of crop-livestock-forest integration systems in Brazil. Pesq. Agrop. Brasileira. 2011;46(10):1-12. Available:http://www.scielo.br/scielo.php?script=sci_arttext&pid=S0100-204X2011001000001 Portuguese
3. Oliveira Neto SN, Reis GG, Reis MGF, Leite HG. Arranjos estruturais do componente arbóreo em sistema agrossilvipastoril e seu manejo por desrama e desbaste. Informe Agropecuário, Belo Horizonte, Portuguese. 2010;31(257):3.
4. Macedo MCM. Crop and livestock integration: the state of the art and the near future. Campo Grande. Revista Brasileira de Zootecnia. 2009;38:133-146. Available:http://www.scielo.br/pdf/rbz/v38nspe/v38nspea15.pdf . Portuguese
5. Monquero PA, Milan B, Silva PV, Hirata ACS. Desiccation timings of soil cover crop before soybean sowing. Planta Daninha, 2010;28(3):561-573. Available:http://www.scielo.br/scielo.php?script=sci_abstract&pid=S0100-83582010000300013&lng=en&nrm=iso . Portuguese
6. Machado LAZ, Assis PGG. Straw and forage production of annual and perennial species in succession to soybean. Pesq. Agrop. Bras. 2010;45(4):415-422. Available:http://www.scielo.br/scielo.php?pid=S0100204X2010000400010&script=sci_arttext. Portuguese
7. Garcia CMP, Andreotti M, Tarsitano MAA, Teixeira Filho MCM, Lima AES, Buzetti S. Agronomic performance of corn and forages species in Crop-Livestock Integration system in the Cerrado. Ciência rural. 2013;43(4):589-595. Available:http://www.scielo.br/scielo.php?pid=S010384782013000400005&script=sci_arttext&tlng=es . Portuguese
8. Vilela L, Martha Junior GB, Macedo MCM, Marchão RL, Guimarães Júnior R, Pulrolnik K, Maciel GA. Integrated crop-livestock systems in the Cerrado region. Pesq. Agrop. Bras., Brasília. 2011;46(10): 1127-1138. Available:http://www.scielo.br/scielo.php?pid=S0100-204X2011001000003&script=sci_arttext&tlng=pt. Portuguese
9. Van Soest PJ, Robertson JB, Lewis BA. Methods for dietary neutral detergent fiber and no starch polysaccharides in relation to animal nutrition. Journal of Dairy Science. 1991;74:3583-3597. Available:https://reader.elsevier.com/reader/sd/pii/S0022030291785512?token=73EF66A5BDEB1511AC0301E35C3A6D41D04383599FFD1E3FEAEDDB17624453C16C3E88DC0CC0B204C415417C3CEFC351
10. Mertens DR. NDF: Fiber composition and value of forages with different NDF concentrations. In: Southwest Nutritional Ecology Management Conference, 1988, Phoenix. Proceedings. Phoenix: Arizona State University. 1998;85-99. Available:https://www.ars.usda.gov/research/publications/publication/?seqNo115=88327
11. Association of Official Analytical Chemists (AOAC). Official methods of analysis. 15.Ed. Washington, D.C., 1990;1298.
12. Gobbi KF, Garcia R, Garcez Neto AF, Pereira OG, Ventrella MC, Rocha GC. Morphological and structural characteristics and productivity of Brachiaria grass and forage peanut submitted to shading. Pesq. Agrop. Bras. 2009;38(9):1645-1654. Available:http://www.scielo.br/scielo.php?pid=S1516-35982009000900002&script=sci_arttext . Portuguese
13. Fontes LD, Oliveira FLR, Santos MV, Fonseca DM, Galvão JCC, Leli DL. Corn hybrids height in different eucalyptus trees distances in systems agroforestry. Mineiro Symposium of Animal Production, 3, Diamantina. Annals. Diamantina: UFVJM. 2015;194-196. Available:http://acervo.ufvjm.edu.br/jspui/bitstream/1/1360/1/iii_simp_altura.pdf . Portuguese
14. Gimenes MJR, Victoria Filho R, Prado EP, Dal Pogetto MHFA, Christovam RS. Interference of forage species with maize. Revista da Faculdade de Zootecnia, Veterinária e Agronomia, Uruguaiana. 2008;15(2):61-76. Available:http://revistaseletronicas.pucrs.br/ojs/index.php/fzva/article/view/2804/3896 . Portuguese

15. Busato C, Busato CCM. Initial growth of corn crop intercropped. Enciclopédia Biosfera. 2011;7:307-316. Available:http://www.conhecer.org.br/enciclop/2011b/ciencias%20agrarias/crescimento%20inicial.pdf . Portuguese
16. Borghi E, Crusciol CAC. Corn yield, spacing and intercropping modalities with *Brachiaria brizantha* in no-tillage system. Pesq. Agrop. Bras. 2007;42(2):163-171. Available:http://www.scielo.br/scielo.php?pid=S0100-204X2007000200004&script=sci_arttext&tlng=es . Portuguese
17. Silva DV, Pereira GAM, Freitas MAM, Silva AA, Seiyama T, Ferreira LR, Cecon PR. Nutritional efficiency of maize in intercropping with signalgrass. Ciência Rural. 2015;38(9):1645-1654. Available:http://www.scielo.br/scielo.php?pid=S0103-84782015000801394&script=sci_arttext&tlng=pt. Portuguese
18. Seidel EP, Gerhardt IFS, Castagnara DD, Neres MA. Effect of time of sowing and system *Brachiaria brizantha* intercropped with maize on yield components and soilphysical properties. Semina: Ciencias Agrárias. 2014;35(1):55-66. Available:http://www.uel.br/revistas/uel/index.php/semagrarias/article/view/10550/14050. Portuguese
19. Freitas FCL, Ferreira LR, Ferreira FA, Santos MV, Agnes EL, Cardoso AA, Jakelaitis A. Implantation of Pastures via Consortium of *Brachiaria brizantha* with Corn for Silage under No-Tillage System. Planta Daninha. 2005;23(1):49-58. Available:http://www.scielo.br/scielo.php?script=sci_arttext&pid=S0100-83582005000100007&lng=en&nrm=iso&tlng=pt . Portuguese
20. Rodrigues PHM, Ruzante JM, Senatore AL, Lima FR, Melotti L, Meyer PM. Evaluation of microbial inoculation on nutritional and fermentative quality of corn Silage. Rev. Bras. De Zootencia. 2004;33(3):538-545. Available:http://www.scielo.br/scielo.php?pid=S1516-35982004000300003&script=sci_arttext&tlng=es. Portuguese
21. Jobim CC, Nussio LG, Reis AR, Schmidt P. Methodological advances in evaluation of preserved forage quality. Rev. Bras. De Zootencia. 2007;36:101-119(supplement). Available:http://www.scielo.br/scielo.php?pid=S1516-35982007001000013&script=sci_arttext. Portuguese
22. Melo MJAF, Backes AA, Fagundes JL, Silva GP, Freire APL. Fermentation characteristics and chemical composition of Tanzania grass silage containing additives. Boletim da Indústria Animal. 2016;73:189-197. Available:http://iz.sp.gov.br/pdfsbia/1475170711.pdf. Portuguese
23. Pegoraro PL, Krahl G, Mantovani. Bromatological composition of corn silage during the period of use at different technological levels. Unoesc & Ciência. 2016;7(1):39-46. Available:https://portalperiodicos.unoesc.edu.br/acbs/article/view/10101/pdf. Portuguese
24. Nussio LG, Campos FP, Dias FN. Importância da qualidade da porção vegetativa no valor alimentício da silagem de milho. Simpósio Sobre Produção e Utilização de Forragens Conservadas, Annals... UEM: SFC. 2001;127-145. Available:https://morfsistzootecn.webnode.com.br/_files/200000099-4672346b7b/Silagens-de-milho-qualidade.pdf. Portuguese
25. Costa NR, Andreotti ML, Keny SM, Santos FG, Pariz CM. Nitrogen fertilization of *Urochloa* grasses intercropped with corn. Pesq. Agrop. Bras. 2014;9. Available:https://www.cabdirect.org/cabdirect/FullTextPDF/2014/20143349949.pdf. Portuguese




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