Yield of maize grain and tropical grass species under intercropping management system using nicosulfuron herbicide in off-season cultivation

Armindo Neivo Kichel¹, Luiz Carlos Ferreira de Souza², Ademar Pereira Serra¹*, Roberto Giolo de Almeida¹

¹Embrapa Beef Cattle, Campo Grande, Mato Grosso do Sul, Brazil
²Universidade Federal da Grande Dourados (UFGD), Post-Graduation Program in Agronomy, City of Dourados, State of Mato Grosso do Sul, Brazil

*Corresponding author: ademar.serra@embrapa.br

Abstract

This research aimed to evaluate the maize grain yield and forage of grass species under intercropping system using nicosulfuron herbicide. In order to assess the parameters related to maize, a randomized block design was defined. The treatments were arranged in a (5 × 2 + 1) × 2 factorial design with four repetitions resulting in 11 treatments, where maize was cultivated under intercropping condition with different forage species (5) (Brachiaria brizantha cv. Marandu, Piatã, Xaraés, Brachiaria ruziziensis and Panicum maximum cv. Mombaça) and maize monoculture (1) as control treatment, with and without nicosulfuron herbicide application (2) in two growing seasons (2014 and 2015). The off-season intercropping of maize with tropical forage grasses with and without herbicide suppression decreased maize grain yield. The suppression with nicosulfuron herbicide decreased the dry matter production of forage grasses. Intercropping of P. maximum cv. Mombaça with maize showed higher decrease in maize grain yield. On the other hand, it showed higher forage grasses production for livestock feeding. B. brizantha cv. Piatã was the forage which less affected maize grain yield under intercropping, even with absence of nicosulfuron suppression. Off-season maize under intercropping with tropical forages can be used to recover degraded pastures; increasing forage dry matter production for livestock, remaining the soil covered with straws with possibility of no-till seeding for the next cultivation.

Keywords: Brachiaria spp, Panicum maximum, intercropped, pasture.
Abbreviations: ICLS_Integrated crop-livestock systems.

Introduction

The integrated crop-livestock systems are commonly used in Brazil, due to many benefits such as recovery of degraded pasture, increasing grain production, use of pasture in winter season for livestock grazing (Crusciol et al., 2014), resulting in higher efficiency of the lands. Aggregation of soil physical property and stability have been shown as a great contribution for production of forage species under rotation with grain crops (Viaud et al., 2018). However, many farmers in Brazil still insist rotation of soybean with maize without insertion of maize intercropping with forage grasses species. The intercropping of maize with forage grasses may be considered as jeopardy for some farms, because of the idea that maize grain yield is decreased due to interspecific competition, besides higher cost of crop-livestock implementation. As reported by Asai et al. (2018), the cost related to collective decision making, monitoring and operational cost are considered critical issues to implement integrated crop-livestock systems.

Intercropping increases the above-ground dry matter and improves the sustainability of no-till seeding, which is widely spread in Brazil and in more than 70% of the farms in South America (Derpsch et al., 2010). However, the time of forage sowing under intercropping is quite important to decrease interspecific competition (Tsumanuma et al., 2012). The simultaneous seeding of maize with forage grasses or seeding the forage at the same time has resulted in different competition depending on the forage species in intercropping (Crusciol et al., 2013). In Brazil, the forage grasses are commonly sown at the same time of maize with the possibility of using herbicide suppression in such occasions.

The no-till system alone is not sufficient for improvement of soil physical, chemical and microbial properties. Thus, the use of livestock into the integrated systems is decisive to have progressive results in terms of soil quality (Lourente et al., 2016). The weather condition in most regions of Brazil allows the cropping of soybean, followed by maize intercropped with forage species (Fortes et al., 2016). Thereafter, it is possible to cultivate soybean followed by maize along with three months of pasture for livestock grazing. Nevertheless, the intercropping of two species usually results in decreasing yield of one in detriment of another (Calonego et al., 2011). In most circumstances, maize is intercropped with B. ruziziensis. However, in tropical climate there are many other options of forage grasses species to be introduced into this intercropping system. The species B. brizantha cv. Marandu, Piatã, Paiaguas, Xaraés and P. maximum cv. Massai, Mombaça, Zuri, can be included among other species of forages grasses.
Effects of herbicide management on ear grain weight and maize grain yield

Spraying of nicosulfuron herbicide to suppress the forages growth in intercropping with maize resulted in significant (P<0.01) increase in grain weight per ear (GWE) and maize grain yield (MGY) (Figure 1A and B). The absence of herbicide on maize intercropping with forages grasses decrease the average GWE on average 7 g, consequently decreasing 450 kg ha⁻¹ of MGY. These results indicated the competition among forage grasses and maize, which must be well comprehended to avoid economic loss. Application of nicosulfuron herbicide at rate of 6 g a.i. ha⁻¹ did not affect grain yield because it did not kill the forage grass species in intercropping with maize. However, in previous researches we observed that 8-16 g a.i. ha⁻¹ of nicosulfuron did not affect maize grain yield in intercropping with Brachiaria ruziziensis (Ceccone et al., 2010). Nevertheless, many other factors are related to the competition of maize intercropping with forage grass, as the case of forage grass stand and the forage grasses species used in intercropping (Pariz 2011; Vidal 2010).

The effects of cropping systems on grain weight per ear, ear length and maize grain yield

Maize intercropping with P. maximum cv. Mombaça resulted in lower GWE in comparison to maize monoculture. However, no significant difference (P>0.05) was observed between the other intercropping in comparison to P. maximum cv. Mombaça (Figure 2A). These results indicated that EGV of maize monoculture did not differ from maize intercropping B. brizantha cv. Marandu, Xaraés, Piata e Brachiaria ruziziensis. Higher ear lengths were observed in maize monoculture and maize intercropping with B. brizantha cv. Xaraés, B. ruziziensis and P. maximum cv. Mombaça (Figure 2B). Conversely, maize intercropping with B. brizantha cv. Marandu and Piata showed lower ear length. However, maize grain yield in monoculture showed higher grain yield in comparison to intercropping. Among intercropping, the markedly difference was between maize intercropping with B. brizantha cv. Piata which showed higher grain yield in comparison to intercropping with P. maximum cv. Mombaça (Figure 2C). The maize intercropping with any forage grass species assessed in this research resulted in decreasing maize grain yield, which achieved the maximum decrease in maize, when intercropped with P. maximum cv. Mombaça that reduced maize grain yield up to 20.15%.

Interactive effects between growing seasons vs. cropping systems

Interactive effects were observed between growing seasons vs. cropping systems on above-ground maize dry matter (AMDM), harvest index (HI) and stem diameter (SD). In 2014 growing season, the AMDM among the cropping systems differed just for maize intercropping with B. ruziziensis, which showed lower amount of AMDM (Figure 3A). On the other hand, in 2015 growing season the results for marandu,
Table 1. Analysis of variance for maize traits intercropped with forage grasses species with and without herbicide suppression in two growing seasons.

| Source of variation | Variables | Blocks | Growing season (GS) | Herbicide management (HM) | Cropping systems (CS) | GSxHM | GSxCS | HMxCS | GSxHMxCS |
|---------------------|-----------|--------|---------------------|---------------------------|----------------------|-------|-------|-------|----------|
|                      |           |        |                     |                           |                      | F-value |       |       |       |          |
| MS                  |           | 3.035* | 5.071*              | 1.016***                  | 0.843**              | 0.004** | 0.316** | 0.792 ns | 0.427 ns |
| NME                 |           | 4.337**| 7.194**             | 1.882**                   | 1.036**              | 0.010** | 0.405** | 0.548 ns | 0.167 ns |
| EL                  |           | 1.863ns| 4.546*              | 0.888**                   | 2.348*               | 0.370** | 0.935** | 0.487 ns | 0.566 ns |
| NRE                 |           | 2.195ns| 56.369**            | 0.076**                   | 5.524*               | 5.385** | 0.385** | 0.839 ns | 1.041 ns |
| GWE                 |           | 5.367**| 6.123**             | 4.853*                    | 3.057**              | 1.925** | 0.785** | 0.319 ns | 0.351 ns |
| 1000GW              |           | 0.904ns| 186.804**           | 0.776*                    | 1.941**              | 1.427** | 0.656** | 0.314 ns | 0.266 ns |
| NGE                 |           | 3.196* | 27.254**            | 1.905*                    | 1.517**              | 0.298** | 0.596** | 0.483 ns | 0.459 ns |
| MGY                 |           | 1.308ns| 57.518**            | 15.943**                  | 19.116**             | 1.940** | 0.976** | 0.118 ns | 0.118 ns |
| ANDN                |           | 0.453ns| 34.673**            | 2.363**                   | 4.267**              | 0.216** | 4.267** | 0.073 ns | 1.073 ns |
| HI                  |           | 0.467ns| 0.392ns             | 2.027**                   | 3.139**              | 2.761*  | 1.024*  | 0.424 ns | 0.424 ns |
| NGR                 |           | 1.121ns| 8.803**             | 0.116**                   | 2.874*               | 1.118** | 1.342** | 0.345 ns | 0.345 ns |
| SD                  |           | 3.253**| 569.258**           | 1.241**                   | 8.577**              | 4.124** | 0.736** | 0.861 ns | 0.861 ns |

*significant at p<0.05; **significant at p<0.01 by F-value; ns = no significant. Maize stand (MS), No. of maize ears (NME), stem diameter (SD), ear diameter (ED), ear length (EL), No. of rows per ear (NRE), No. of grain per row (NGR), 1000 grains weight (100GW), maize grain yield (MGY), grain weight per ear (GWE), No. of grain per ear (NGE), above ground maize dry matter (AMDM), and harvest index (HI).

Fig 1. Grain yield per ear and maize grain yield affected by the herbicide management to suppress forage growth. Means followed by the same uppercase letters do not differ by t-test of means at 5% probability.

Table 2. T-test of means for maize traits compared in two cropping seasons.

| Variables            | Growing seasons | Mean ± standard error                  |
|----------------------|-----------------|----------------------------------------|
| Maize stand          | 2014            | 54,745.33 ± 322A                       |
|                      | 2015            | 52,314.77 ± 1,012B                     |
| No. of ears per hectare | 2014    | 54,050.83 ± 346A                       |
|                      | 2015            | 51,018.47 ± 1,080B                     |
| Ear length           | 2014            | 12.45 ± 0.079A                         |
|                      | 2015            | 12.03 ± 0.187B                         |
| Grain weight per ear | 2014            | 116.17 ± 1.178A                        |
|                      | 2015            | 109.09 ± 2.929B                        |
| 1000 grain weight    | 2014            | 361.03 ± 2.416A                        |
|                      | 2015            | 293.46 ± 4.342B                        |
| No. of grain rows per ear | 2014 | 14.49 ± 0.115B                         |
|                      | 2015            | 15.68 ± 0.111A                         |
| No. of grain per ear | 2014            | 335.30 ± 2.66B                         |
|                      | 2015            | 391.96 ± 3.11A                         |
| Maize grain yield    | 2014            | 6,279.35 ± 52,1A                       |
|                      | 2015            | 5,475.86 ± 43,2B                       |

Means followed by the same uppercase letters do not differ by t-test of means at 5% probability.
Growing season 2015
Growing season 2014

Above-ground maize dry matter (kg ha\(^{-1}\))

Harvest index (%)

Ear length (cm)

Stem diameter (cm)

Grain weight per ear (g)

Maize grain yield (kg ha\(^{-1}\))

Fig 2. Grain weight per ear (A), ear length (B) and maize grain yield (C) affected by cropping systems. Maize monoculture (MM), maize intercropping with *Brachiaria bazioni* cv. Marandu (MMa), Xaraés (MXa), Piatã (MPI), maize intercropping with *B. ruziei*nis, and *P. maximum* cv. Mombaça. Means followed by the same uppercase letters do not differ by t-test of means at 5% probability. CV=coefficient of variation.

Table 3. Summary of analysis of variance (ANOVA) for above-ground forage dry matter under intercropping with maize with and without herbicide suppression in two growing seasons.

| Source of variation | Degrees of freedom | Median square | F-value | P-value |
|---------------------|--------------------|--------------|---------|---------|
| Growing season (GS) | 1                  | 25847421.612 | 123.957 | 0.0000  |
| Herbicide management (HM) | 1 | 214155673.512 | 1027.034 | 0.0000 |
| Cut age (CA) | 3 | 343095559.208 | 1645.396 | 0.0000 |
| Cropping systems (CS) | 4 | 11766157.910 | 56.427 | 0.0000 |
| Block | 3 | 203392.208 | 0.975 | 0.4048 |
| GS*HM | 1 | 3287794.050 | 15.767 | 0.0001 |
| GS*CS | 4 | 15536693.320 | 74.510 | 0.0000 |
| HM*CS | 1 | 991988.839  | 4.757  | 0.0010 |
| HM*CA | 4 | 917918.598 | 4.402 | 0.0019 |
| CA*CS | 12 | 1221713.085 | 5.859 | 0.0000 |
| HM*CA*CS | 12 | 385698.577 | 1.850 | 0.0412 |
| GS*HM*CA | 3 | 3533803.675 | 16.947 | 0.0000 |
| GS*CA*CS | 12 | 729364.130 | 3.498 | 0.0001 |
| GS*HM*CS | 4 | 3287794.050 | 0.4809 | 0.4809 |
| Error | 249 | 208518.551 | | |

Fig 3. Interactive effects between growing seasons and cropping systems under above-ground maize dry matter (A), harvest index (B), and stem diameter (C). Means followed by the same uppercase letters do not differ by t-test of means at 5% probability. Maize monoculture (MM), maize intercropping with *Brachiaria bazioni* cv. Marandu (MMa), Xaraés (MXa), Piatã (MPI), maize intercropping with *B. ruziei*nis, and *P. maximum* cv. Mombaça. Means followed by the same uppercase letters do not differ by t-test of means at 5% probability. CV=coefficient of variation.
Table 4. Interactive effects of herbicide management vs. cropping systems vs. cut age on above-ground forage dry matter.

| Herbicide management | Cropping systems  | Cut age - DAE | Equation |
|----------------------|-------------------|---------------|----------|
| MMa                  | 473Bb             | 1121Bb        | 2011Bb   | Y=1048.621-21.018x+0.2185x² R²=0.99 |
| MMa                  | 523Bb             | 1154Bb        | 2405Bb   | Y=168.445+1.0068x+0.1156x² R²=0.99 |
| MMo                  | 593Bb             | 1629Bb        | 3398Bb   | Y=1041.026+52.276x-0.0113x² R²=0.98 |
| MR                   | 501Bb             | 1132Bb        | 1894Bb   | Y=–223.493+9.872x+0.1236x² R²=0.99 |
| MP                   | 593Bb             | 1201Bb        | 2513Bb   | Y=1096.773-21.531x+0.2416x² R²=0.98 |
| MMa                  | 1150Ab            | 2224Ac        | 4312Ac   | Y=2423.842-46.261x+0.945x⁻¹-0.003x² R²=0.99 |
| MMa                  | 1094Ab            | 2304Ac        | 4250Ac   | Y=1014.995-19.870x+0.490x⁻¹+0.001x² R²=0.99 |
| MMo                  | 1631Aa            | 3336Aa        | 6032Aa   | Y=2287.165-57.963x+1.050x⁻¹-0.003x² R²=0.99 |
| MR                   | 1867Aa            | 2574Ab        | 4659Ab   | Y=3673.459-87.574x+1.106x⁻¹-0.003x² R²=0.99 |
| MMa                  | 1312Ab            | 2980Aab       | 5276Ab   | Y=1330.348-35.662x+0.828x⁻¹-0.003x² R²=0.99 |
| MMa                  |                 |               |          | |

Means followed by the same uppercase letters do not differ between herbicide management in each cut age by t-test of means at 5% probability, and the same lowercase letter do not differ among the cropping systems in each cut age and herbicide management by Tukey test of means at 5% probability.

Fig 4. Interactive effects of growing season vs. herbicide management vs. cut age on above-ground forage dry matter.

Table 5. Experimental treatments assessed and respective abbreviation.

| Cropping systems                  | Nicosulfuron herbicide management | Abbreviation |
|-----------------------------------|----------------------------------|--------------|
| Maize monoculture                 | No                               | MM           |
| Maize intercropping with Brachiaria brizantha cv. Xaraés | Yes                             | MXHS         |
| Maize intercropping with Brachiaria brizantha cv. Piátã | Yes                             | MPHA         |
| Maize intercropping with Panicum maximum cv. Mombaça | Yes                             | MMPoH         |
| Maize intercropping with Brachiaria rustigens cv. Kenedy | Yes                             | MRHS         |
| Maize intercropping with Brachiaria brizantha cv. Marandu | No                              | MMAaS        |
| Maize intercropping with Brachiaria brizantha cv. Piátã | No                              | MMAa         |
| Maize intercropping with Panicum maximum cv. Mombaça | No                              | MMPoA        |
| Maize intercropping with Brachiaria rustigens cv. Kenedy | No                              | MRRa         |
| Maize intercropping with Brachiaria brizantha cv. Marandu | No                              | MMPoA        |
| Maize intercropping with Brachiaria brizantha cv. Xaraés | No                              | MMPoA        |

Fig 5. Rainfall (mm), maximum and minimum temperature (ºC) per decennia from February (2014) to August (2014). Source: climate station of Universidade Federal da Grande Dourados (UFGD).
xaraes and mombaça were not equal, which demonstrate that AMDM can change with the weather conditions in each year, but ruziziensis and piatã remained without alteration. This stability was observed for harvest index in ruziziensis and piatã (Figure 3B). When the weather condition was more favorable for maize growth, the stem diameter showed higher values, as the case of higher rainfall in 2015 growing season. However, the competition between maize and forage grasses resulted in lower SD in intercropping compared to maize monoculture (Figure 3C).

**Production of dry matter in forage grasses in intercropping with maize**

The dry matter production of forage grasses species in intercropping with maize showed interactive effect for growing seasons vs. herbicide management vs. cutting age and herbicide management vs. cut age vs. cropping systems (Table 3). Thus, the interaction effects resulted in adjustment of regression models for cutting age of forages grasses.

For both growing seasons (2014 and 2015) we observed significant effect of herbicide management, which decreased above-ground forage dry matter (AFDM) (Figure 4). In 2014 growing season, the herbicide management was sprayed at 50 days after emergency (DAE) causing 63.7% reduction in AFDM in relation to absence of herbicide suppression. However, in 2015 growing season the same age achieved 45.9% of AFDM reduction. The herbicide suppression effects remained in the course of time until 180 DAE (Figure 4).

Harvesting maize at 135 DAE, showed that highest increment in AFDM was observed due to higher light incidence. At 180 DAE, the AFDM in 2014 growing season showed on average 4,000 kg ha⁻¹ with herbicide suppression and 5,289 kg ha⁻¹ without suppression. In 2015 growing season, the average AFDM was 5,359 kg ha⁻¹ with herbicide suppression and 7,818 kg ha⁻¹ without herbicide suppression. As reported by Borghi et al. (2007), the shade of maize plants in intercropping with forage grasses decreased the leaves productions. Therefore, at the end of maize life cycle the sun light increases forage grasses photosynthesis, resulting in increment of forage biomass.

The suppression on forage grass species with below-rate nicosulfuron herbicide (6 g ha⁻¹), sprayed at 20 DAE, decreased the AFDM about 60.95%, 53.54%, 50% and 27.53%, correspond to evaluation time of 50, 90, 135 and 180 DAE, respectively. On average, the absence of herbicide suppression in two cropping seasons increased 34% of AFDM in 45 days (from 135 to 180 DAE) (Table 4). However, nicosulfuron spray increased 95% of AFDM from 135 to 180 DAE. The increment in AFDM was consequences of higher tillers and leaf growth after the effect of herbicide suppression and maize competition with forages grasses species.

In 50 DAE, the AFDM among the intercropping with maize did not differ under herbicide suppression. However, in the evaluation accomplished without herbicide suppression there was significant difference among the intercropping, resulting in higher AFDM for P. maximum cv. Mombaça and B. ruziziensis. Nevertheless, for evaluations at 90, 135 and 180 DAE, P. maximum cv. Mombaça showed higher AFDM than other forage grass species using either herbicide and without suppression. It followed by B. brizantha cv. Piatã (Table 4). The increase in P. maximum cv. Mombaça dry matter resulted in decreasing maize grain yield, suggesting the competition between these species.

**Materials and Methods**

**Site and soil description**

This research was carried out in a Latossolo Vermelho (Rhodic Hapludox), with clayey texture and clay mineralogy constituted mainly by Al/Fe oxy-hydroxides (Santos et al., 2013). The experimental site is located in the municipality of Dourados, state of Mato Grosso do Sul, Brazil (22°14’08” S, 59°54’13” W, and 455 m above sea level). Soil samples were collected (0–0.20 m depth) in January 2014, before the establishment of the experiment in order to define the fertilizer rates and determine soil chemical and physical properties (Claessen, 1997): pH (CaCl2), 5.34; 22.08 g dm⁻³ organic matter; 21.7 mg dm⁻³ P; 0.28 cmol; dm⁻³ K⁺; 4.56 cmol; dm⁻³ Ca²⁺; 2.04 cmol; dm⁻³ Mg²⁺; 5.09 cmol; dm⁻³ H⁺Al; 0 cmol; dm⁻³ Al³⁺; 8.68 cmol; dm⁻³ sum of base; 11.97 cmol; dm⁻³ cations exchange capacity (CEC); 57.5% base saturation; and 610, 90 and 300 g kg⁻¹ of clay, silt and sand, respectively.

Rainfall data, maximum and minimum temperature in the experimental site are shown in Figure 5. Maize was cultivated from February to August of 2014 and 2015 growing seasons. According to Köppen (1948), the region has tropical climate (Cwa), with rainy summer and dry winter, with average rainfall of 1,428 mm and annual average temperature of 22.7°C (Arai et al., 2010).

**Experimental design and treatment implementation**

In order to assess the parameters related to maize, randomized blocks experimental design was defined, with the treatments arranged in a (5 × 2 +1) × 2 factorial design, with four repetitions, resulting in 11 treatments with maize cultivated under intercropping with different forage grass species (5) [Brachiaria brizantha cvs. (Marandu, Piatã and Xaraés), Brachiaria ruziziensis and Panicum maximum cv. Mombaça] and maize monoculture (1) as the control treatment, with and without nicosulfuron herbicide suppression (2) in two growing seasons (2014 and 2015) (Table 5).

The parameters related to above-ground dry matter production of maize intercropping with forage grasses species were arranged in a factorial design (5×2×2x2), which was compiled by cropping systems with forage grasses species (5) [Brachiaria brizantha cvs. (Marandu, Piatã and Xaraés), Brachiaria ruziziensis and Panicum maximum cv. Mombaça], with and without nicosulfuron herbicide management in two growing seasons (2014 and 2015) in four repetitions. In order to determine the above-ground dry matter of forage grasses at cutting ages [50, 90, 135 and 180 days after emergence (DAE)], the experimental design was arranged in a 5×4×2x2 factorial, with cropping systems under five forages species [Brachiaria brizantha cvs. (Marandu, Piatã and Xaraés), Brachiaria ruziziensis and Panicum maximum cv. Mombaça] vs. cutting age [50, 90, 135 and 180 days after emergence (DAE)] vs. herbicide management (with and without nicosulfuron herbicide suppression) vs. growing seasons (2014 and 2015), with four repetitions.
The following variables were determined at harvest: maize stand (MS), No. of maize ears (NME), stem diameter (SD), ear diameter (ED), ear length (EL), No. of rows per ear (NRE), No. of grain per row (NGR), 1000 grains weight (100GW), maize grain yield (MGY), grain weight per ear (GWE), No. of grain per ear (NGE), above-ground maize dry matter (AMDM), and harvest index (HI).

The MS and NME per hectare were determined counting the No. of plants and ear in 9 m² in each plot and extrapolated to hectare. SD, ED and EL were determined after maize harvested manually with digital dial calipers, measuring the ear and stem diameter of central part. Ear length was measured by assistance of gradual rule in millimeters from base to top of ear, which was determined in 10 ears in each plot. NRE and NGR were determined after maize harvesting in 10 ears per plot. The 1000 GW were determined according to seed analysis rules (Brazil, 2009).

The maize grain yield (GY) was evaluated after harvesting and the moisture was corrected to 13%. To correct the grain moisture (GM) the following equation was applied: GM=[(IM - CM)/ (100 - CM)],100, where IM=initial moisture and CM=commercial moisture (13%). AMDM was determined by cutting the whole plant from soil surface and drying at 65°C with forced until constant weight, and the HI was determined as Gruzska (2012).

All the measurements for forage grasses were accomplished in 9 m² as reported by maize measurement, which compiles the useful area of evaluation in each plot. In order to determine forage grasses stand, two randomized samples were used with the assistance of iron square with dimension of 1 x 1 m at 25 days after emergence. The above-ground forages dry matter (AFDM) was determined with the assistance of iron square of 1 x 1 m at 50, 90, 135 and 180 days after emergence in both growing season. AFDM was determined by cutting the whole plant from soil surface and dried at 65°C with forced until constant weight, resulting in dry matter defined in kg ha⁻¹.

Statistical analysis

The variables evaluated in the experiment were submitted to the analysis of variance (ANOVA) by the F-test (P≤0.01) using the SISVAR statistical analyses software and the averages of qualitative variables were compared with Tukey (P≤0.05). In the case of significant (P≤0.01) difference in forage grass cutting ages, they were analysed by polynomial equation. The correlation matrix of Person for dependable variables were defined according to relation degrees between variables and the correlation strength was defined as Hinkle et al. (2003).

Conclusion

The intercropping of maize off-season with forage grasses species with and without nicosulfuron herbicide management decreased maize grain yield. B. brizantha cv. Piatã was the forage grass that less affected maize grain yield under intercropping, even with absence of nicosulfuron herbicide suppression. The suppression with nicosulfuron herbicide decreased the dry matter production of forage grasses species. Intercropping of P. maximum cv. Mombaça with maize off-season showed the highest decrease in maize grain yield along with increased forage dry matter to avoid data disturbed, resulting in 9 m² of useful area in each plot. The following variables were determined at harvest: maize stand (MS), No. of maize ears (NME), stem diameter (SD), ear diameter (ED), ear length (EL), No. of rows per ear (NRE), No. of grain per row (NGR), 1000 grains weight (100GW), maize grain yield (MGY), grain weight per ear (GWE), No. of grain per ear (NGE), above-ground maize dry matter (AMDM), and harvest index (HI).

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The variables evaluated in the experiment were submitted to the analysis of variance (ANOVA) by the F-test (P≤0.01) using the SISVAR statistical analyses software and the averages of qualitative variables were compared with Tukey (P≤0.05). In the case of significant (P≤0.01) difference in forage grass cutting ages, they were analysed by polynomial equation. The correlation matrix of Person for dependable variables were defined according to relation degrees between variables and the correlation strength was defined as Hinkle et al. (2003).

Conclusion

The intercropping of maize off-season with forage grasses species with and without nicosulfuron herbicide management decreased maize grain yield. B. brizantha cv. Piatã was the forage grass that less affected maize grain yield under intercropping, even with absence of nicosulfuron herbicide suppression. The suppression with nicosulfuron herbicide decreased the dry matter production of forage grasses species. Intercropping of P. maximum cv. Mombaça with maize off-season showed the highest decrease in maize grain yield along with increased forage dry matter to avoid data disturbed, resulting in 9 m² of useful area in each plot. The following variables were determined at harvest: maize stand (MS), No. of maize ears (NME), stem diameter (SD), ear diameter (ED), ear length (EL), No. of rows per ear (NRE), No. of grain per row (NGR), 1000 grains weight (100GW), maize grain yield (MGY), grain weight per ear (GWE), No. of grain per ear (NGE), above-ground maize dry matter (AMDM), and harvest index (HI).

The MS and NME per hectare were determined counting the No. of plants and ear in 9 m² in each plot and extrapolated to hectare. SD, ED and EL were determined after maize harvested manually with digital dial calipers, measuring the ear and stem diameter of central part. Ear length was measured by assistance of gradual rule in millimeters from base to top of ear, which was determined in 10 ears in each plot. NRE and NGR were determined after maize harvesting in 10 ears per plot. The 1000 GW were determined according to seed analysis rules (Brazil, 2009).

The maize grain yield (GY) was evaluated after harvesting and the moisture was corrected to 13%. To correct the grain moisture (GM) the following equation was applied: GM=[(IM - CM)/ (100 - CM)],100, where IM=initial moisture and CM=commercial moisture (13%). AMDM was determined by cutting the whole plant from soil surface and drying at 65°C with forced until constant weight, and the HI was determined as Gruzska (2012).

All the measurements for forage grasses were accomplished in 9 m² as reported by maize measurement, which compiles the useful area of evaluation in each plot. In order to determine forage grasses stand, two randomized samples were used with the assistance of iron square with dimension of 1 x 1 m at 25 days after emergence. The above-ground forages dry matter (AFDM) was determined with the assistance of iron square of 1 x 1 m at 50, 90, 135 and 180 days after emergence in both growing season. AFDM was determined by cutting the whole plant from soil surface and dried at 65°C with forced until constant weight, resulting in dry matter defined in kg ha⁻¹.

Statistical analysis

The variables evaluated in the experiment were submitted to the analysis of variance (ANOVA) by the F-test (P≤0.01) using the SISVAR statistical analyses software and the averages of qualitative variables were compared with Tukey (P≤0.05). In the case of significant (P≤0.01) difference in forage grass cutting ages, they were analysed by polynomial equation. The correlation matrix of Person for dependable variables were defined according to relation degrees between variables and the correlation strength was defined as Hinkle et al. (2003).

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production for livestock. Maize intercropping with forage grasses is a viable alternative to increase maize grain yield, forage grasses dry matter and remaining the soil covered with straws with possibility of no-till seeding for next cultivation, resulting in higher sustainability of agricultural systems.

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