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

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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

(Borghi et al., 2013a; Crusciol et al., 2010). Conversely, the interspecific competition and consequently decreasing of maize grain yield tends farmers to refrain cultivation of the most species mentioned above. Freitas et al. (2014), reported that there is competition between maize with *B. brizantha* cv. BRS Piatã and the application of below-rate of nicosulfuron herbicide (8 g a.i. ha^{-1}) may decrease this competition, especially under higher *B. brizantha* cv. BRS Piatã seeding rate (4 to 6 kg ha^{-1} of viable pure seeds).

In order to obtain the maximum benefits of maize intercropping with forage species, it is relevant to figure out the degree of competition between species to make the viability of this intercropping possible. The study of herbicide suppression management, associated with different forage grass species under intercropping with maize might achieve the best combination, resulting in better grain yield, forage dry matter production and increment in farmer economic returns.

This research aimed to evaluate the yield of some forage grass species and maize grain yield under intercropping with nicosulfuron herbicide suppression to explore better alternative for maize grain yield, forage grass production and soil covered with straws for no-till seeding.

Results and Discussion

Analysis of variance (ANOVA) of the parameters assessed

The growing seasons affected the majority of analyzed variables, except for harvest index (HI) (Table 1). Herbicide management showed significant difference only for ear grain weight (EGW) and maize grain yield (MGY) (Table 1). The cropping systems (maize intercropping with forage grass species) resulted in significant effect on MGY, above-ground maize dry matter (AMDM), stem diameter (SD), ear length (EL), EGW, No. of grain per row (NGR) and HI (Table 4). Besides the major effect of the treatments, interactive effect was observed for growing seasons *vs.* cropping systems on No. of grain row per ear (NGRE) and interactive effects on growing seasons *vs*. cropping systems on AMDM, HI and SD.

The intercropped forage grass species can affect EL, EGW, NGR, HI, SD, AMDM and MGY. However, no significant effect of forages species among the cropping systems was observed for No. of ear per hectare (NE), NGR, 1000 grain weight (1000-GW) and NGE.

Growing seasons affects maize traits

The first growing season (2014) showed better results for maize stand (MS), No. of ear per hectare (NEH), EL, EGW, 1000-GW and MGY. However, in 2015 growing season a higher NGE and NGR was observed (Table 2).

Even with higher rainfall in 2015 growing season, the MGY showed 16.80% less grain yield which was related to lower radiation due to many cloudy days resulted to 215 mm rainfall during May 2015. These conditions occurred during the R1 and R3 reproductive maize stage. As reported by Didonet et al. (2002), decreasing in soil radiation ranges from 30% to 40% can decline the maize productive potential, which may decrease the photosynthesis capacity and consequently reduction in maize grain yield.

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* (Ceccon 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 EGW of maize monoculture did not differ from maize intercropping *B. brizantha* cv. Marandu, Xaraés, Piatã 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 Piatã 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. Piatã 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^{ns}	0.843^{ns}	0.004^{ns}	0.316^{ns}	0.792 ^{ns}	0.427 ^{ns}
NME	4.337**	7.194**	1.882^{ns}	1.036^{ns}	0.010^{ns}	0.405^{ns}	0.548 ^{ns}	0.167^{ns}
EL	1.863^{ns}	4.546*	0.888^{ns}	2.348*	0.370^{ns}	0.935^{ns}	0.487 ^{ns}	0.566 ^{ns}
NRE	2.195^{ns}	56.369**	0.076^{ns}	0.582^{ns}	5.524*	0.385^{ns}	0.839 ^{ns}	1.041 ^{ns}
GWE	5.367**	6.123**	4.853*	3.057*	1.925^{ns}	0.785^{ns}	0.319 ^{ns}	0.351 ^{ns}
1000GW	0.904^{ns}	186.804**	0.776^{ns}	1.941^{ns}	1.427^{ns}	0.656^{ns}	1.345 ^{ns}	0.266 ^{ns}
NGE	3.196*	27.254**	1.905^{ns}	1.517^{ns}	0.298^{ns}	0.596^{ns}	0.483 ^{ns}	0.459 ^{ns}
MGY	1.308^{ns}	57.518**	15.943**	12.116**	1.940^{ns}	1.987^{ns}	0.706 ^{ns}	0.118 ^{ns}
ANDN	0.453^{ns}	34.673**	2.363^{ns}	4.267**	0.216^{ns}	2.512*	0.555 ^{ns}	0.073 ^{ns}
HI	0.467^{ns}	0.392^{ns}	2.027^{ns}	2.624*	3.139 ^{ns}	2.761*	1.024 ^{ns}	0.424 ^{ns}
NGR	1.121^{ns}	8.803**	0.116^{ns}	2.874*	1.118 ^{ns}	1.342 ^{ns}	1.307 ^{ns}	0.345 ^{ns}
SD	3.253*	569.258**	1.241^{ns}	8.577**	2.331^{ns}	4.124**	0.736 ^{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).

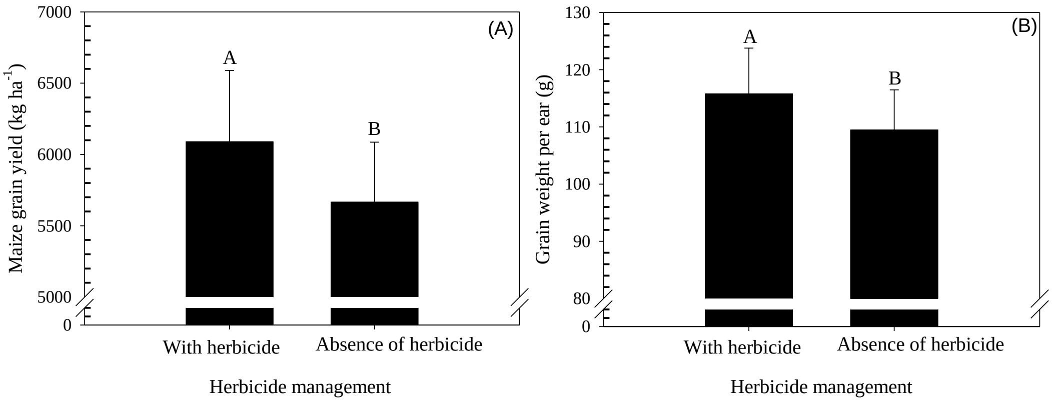

Fig 1. Grain yield per ear and maize grain yield affected by the herbicide management to suppress forage growth. Means followed by the same uppercase letters do not differ by t-test of means at 5% probability.

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.

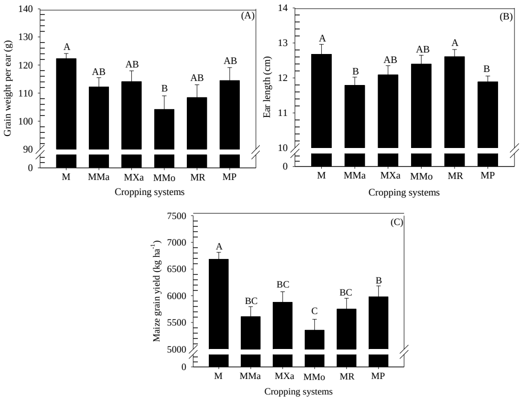

Fig 2. Grain weight per ear (A), ear length (B) and maize grain yield (C) affected by cropping systems. Maize monoculture (MM), maize intercropping with *Brachiaria brizantha* cv. Marandu (MMa), Xaraés (MXa), Piatã (MPi), maize intercropping with *B. ruziziensis*, and *P. maximum* cv. Mombaça. Means 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
GS*CA	3	991988.839	4.757	0.0010
HM*CS	4	917918.598	4.402	0.0019
HM*CA	3	9191820.304	44.082	0.0000
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	181952.026	0.873	0.4809
Error	249	208518.551		

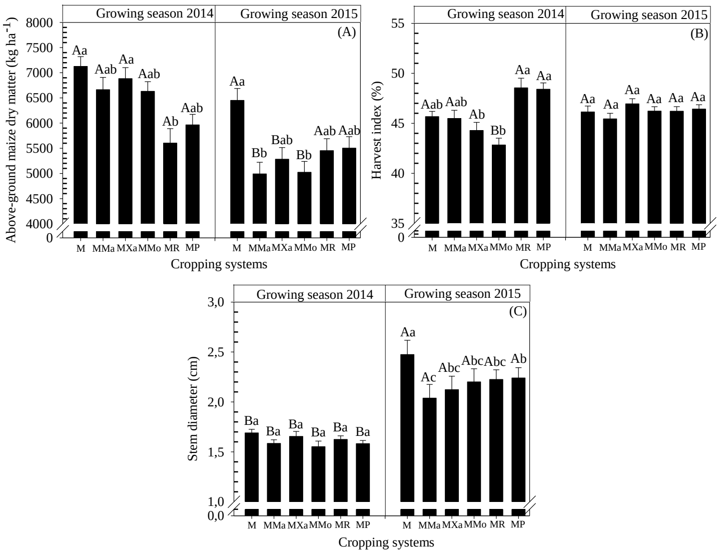

Fig 3. Interactive effects between growing seasons and cropping systems under above-ground maize dry matter (A), harvest index (B), and stem diameter (c). Means followed by the same uppercase letters do not differ by t-test of means at 5% probability. Maize monoculture (MM), maize intercropping with *Brachiaria brizantha* cv. Marandu (MMa), Xaraés (MXa), Piatã (MPi), maize intercropping with *B. ruziziensis*, 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.

		Cut age - DAE				
Herbicide management	Cropping systems	50	90	135	180	Equation
Herbicide suppression	MMa	473Ba	1121Bb	2011Bb	4405Bcd	$Y=1048.621-21.018x+0.2185x^2$ $R^2=0.99$
	MXa	523Ba	1154Bb	2450Bb	4082Bd	$Y=168.445+1.008x++0.1156x^2$ $R^2=0.99$
	MMo	593Ba	1629Ba	3398Ba	5548Ba	$Y=-1041.026+52.276x-0.0113x^2$ $R^2=0.98$
	MR	501Ba	1132Bb	1894Bb	4806Bbc	$Y=-223.493+9.872x+0.1236x^2$ $R^2=0.99$
	MP	593Ba	1201Bb	2513Bb	5075Bab	$Y=1096.773-21.531x+0.2416x^2$ $R^2=0.98$
Absence of herbicide suppression	MMa	1150Ab	2224Ac	4312Ac	5961Ac	$Y=2423.842-66.261x+0.945x^2-0.003x^3$ $R^2=0.99$
	MXa	1094Ab	2304Ac	4250Ac	6169Abc	$Y=1014.995-19.870x+0.490x^2-0.001x^3$ $R^2=0.99$
	MMo	1631Aa	3336Aa	6032Aa	7929Aa	$Y=2287.165-57.963x+1.050x^2-0.003x^3$ $R^2=0.99$
	MR	1687Aa	2574Abc	4659Abc	6321Abc	$Y=3673.459-87.574x+1.106x^2-0.003x^3$ $R^2=0.99$
	MP	1312Ab	2980Aab	5276Ab	6621Ab	$Y=1330.348-35.662x+0.828x^2-0.003x^3=$ $R^2=0.99$

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.

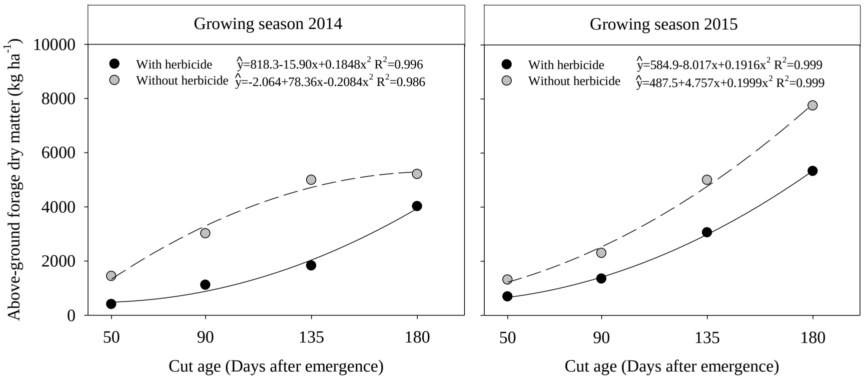

Fig 4. Interactive effects of growing season vs. herbicide management vs. cut age on above-ground forage dry matter.

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 brizanth*a cv. Piatã	Yes	MPHS
Maize intercropping with *Panicum maximum* cv. Mombaça	Yes	MMoHS
Maize intercropping with *Brachiaria ruziziensis* cv. Kenedy	Yes	MRHS
Maize intercropping with *Brachiaria brizantha* cv. Marandu	Yes	MMaSS
Maize intercropping with *Brachiaria brizanth*a cv. Piatã	No	MPHA
Maize intercropping with *Panicum maximum* cv. Mombaça	No	MMoHA
Maize intercropping with *Brachiaria ruziziensis* cv. Kenedy	No	MRHA
Maize intercropping with *Brachiaria brizantha* cv. Marandu	No	MMaHA
Maize intercropping with *Brachiaria brizantha* cv. Xaraes	No	MMaHA

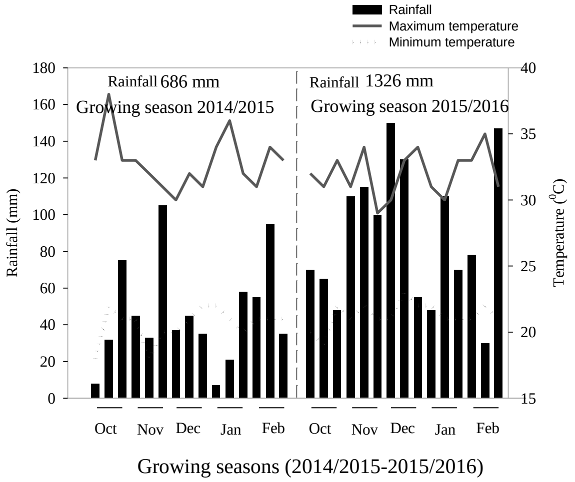

Fig 5. Rainfall (mm), maximum and minimum temperature (Cº) per decennia from February (2014) to August (2014). Source: climate station of Universidade Federal da Grande Dourados (UFGD).

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 conmpared 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$_c$ dm^{-3} K$^+$; 4.56 cmol$_c$ dm^{-3} Ca^{2+}; 2.04 cmol$_c$ dm^{-3} Mg^{2+}; 5.09 cmol$_c$ dm^{-3} H+Al; 0 cmol$_c$ dm^{-3} Al^{3+}; 8.68 cmol$_c$ dm^{-3} sum of base; 11.97 cmol$_c$ 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 22.7ºC (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 grasses 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 (5x2x2), 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 5x4x2x2 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.

Experiment implementation

The experiment was implemented right after soybean harvest on March 15th, 2014, with simultaneous seeding of maize and forage grasses species. The maize harvest was accomplished on August 2th, 2014 and the forages evaluation in September 2014, the experiment was repeated at the same date in 2015. Each experimental unit had 15 m of width and 20 m of length (300 m^2), with 11 units per blocks (3,300 m^2), with four blocks. The seeding and all managements were conducted mechanically. Maize and forages sowing were conducted at the same date on March 14th and 16th 2014 and 2015, which showed five days after sowing to emergency of maize and seven days for forages species.

Before seeding of forage grass species, the seed qualities were evaluated in order to pattern the seeds in relation to cultural values (CV). The samples were collected in an amount of 500 grams for each forage grass species, in which the purity and germination were determined. All the seeds were adjusted following the equation: CV=(germination x purity)/100, express in percentage, since CV=80% for *Brachiaria* and 50% for *Panicum*. The values related to the 1,000 seeds weight and the numbers of seeds per grams were obtained from eight samples (Table 2). The seeding rate for all forages species were determined based on seeds per square meter, aimed to obtain the same number of plants and uniformity to establish the forages. The seeding for *Brachirias* comprised of 70 viable pure seeds (VPS) per square meters, and for *Panicum* 350 VPS per square meter, resulting in 30 plants per square meter for *Brachiaria* and 60 plants per square meter for *Panicum*, as recommendation of Almeida et al. (2009).

The forages seeding was accomplished with a seeding drill before cultivation of maize, with eight rows space apart 0.4 m under no-till, with the seeds deposited 2-4 cm depth. The maize simple hybrid DKB 177 VT PRO was sown under no-till right after forages species, except for treatments with monoculture of forages. The maize seeding was accomplished with seeding-drill with four rows spaced apart in 0.9 m adjusted to seed 6-7 seeds per meter, in 2-5 cm deeper, resulting in an ending stand of 60,000 plants per hectare.

The fertilizer rate for maize was 250 kg ha^{-1} of the formula 08-20-20 (N-P-K) without topdressing N-fertilizer on the experiment. The cultural treats during maize and forages development were occurred at 18 to 20 days after forages emergence, in which atrazine herbicide (1,500 g ha^{-1}) was applied in the whole area to control broadleaf weeds. To control *Spodoptera frugiperda*, we applied the insecticide flubendiamida (70 ml ha^{-1} in growth stage 6) and beta-ciflutrina associated with imidaclopid (500 ml e.a. ha^{-1} in growth stage 8).

The treatments related to the herbicide management was conducted with the herbicide nicosulfuron (6 g a.i. ha^{-1}), which was applied just in the treatments with forage with herbicide suppression when the forage showed one to four tillers (18 to 20 days after emergency of forage grasses).

Plant material and measurement

The maize harvest was occurred on August 2th, 2014 and 2015 growing seasons. In order to assess the maize variables, two rows with 5 m of length were collected, excluding the edges to avoid data disturbed, resulting in 9 m^2 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 m^2 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 (MGY) 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^{0}C with forced until constant weight, and the HI was determined as Gruzska (2012).

All the measurements for forage grasses were accomplished in 9 m^2 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 emergency. 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^{0}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 ($P \leq 0.01$) using the SISVAR statistical analyses software and the averages of qualitative variables were compared with Tukey ($P \leq 0.05$). In the case of significant ($P \leq 0.01$) difference in forage grass cutting ages, they were analysed ny 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 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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