WEEDS INFESTATION IN CORN INTERCROPPED WITH FORAGES AT DIFFERENT PLANTING DENSITIES[1]

Infestação de Plantas Daninhas em Milho Consorciado com Espécies Forrageiras em Diferentes Densidades de Semeadura

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ABSTRACT - Corn is planted in the Center West region of Brazil as a second crop, following soybeans or beans. Intercropping of *Brachiaria* species with corn as a second crop increases the mulching in the cropping system. This study aimed to evaluate the weeds infestation in soybeans following corn/forages intercrop, as a function of corn plant structure, forage species and density. Experiments were conducted in a completely randomized blocks design with four replications, in Ponta Porã and Dourados municipalities, Mato Grosso do Sul state, Brazil, in 2010/2011. Treatments consisted of three corn hybrids with distinct plant architectures intercropped with three forage species: *Brachiaria ruziziensis*, *B. brizantha* and *B. decumbens*, at five densities, and the resulting dry mass was maintained throughout the winter. During the following cropping season, forages were desiccated prior to planting soybeans, and the dry mass of weeds, dry mass of the mulching, soil coverage by weeds, and the broadleaf/grass weed species index (WPI) were determined 15 days after soybean emergence, submitted to an F-test, and analyzed either by regression or by multiple mean comparison, according to the nature of the data. When intercropping corn with species of *Brachiaria*, a reduction in the overall weeds infestation may always be expected; among the studied forage species, more problems with weeds may be anticipated in areas with a less competitive species, e.g. *B. ruziziensis*. Under the conditions of the trials, *B. brizantha* and *B. decumbens* were more capable of inhibiting the emergence of weed species in the winter.

Keywords: *Brachiaria*; weed proportion index; winter crop; mulching

RESUMO - O milho é cultivado na região Centro-Oeste do Brasil na segunda safra, após soja ou feijão. O consórcio de braquiárias com milho segunda safra aumenta o volume de palha no sistema. Objetivou-se com este estudo avaliar a infestação de plantas daninhas na soja pós-consórcio milho/braquiária, em função da arquitetura das plantas do milho, da espécie forrageira e de sua densidade de semeadura. Experimentos foram instalados em blocos casualizados com quatro repetições, nos municípios de Ponta Porã e Dourados, Estado de Mato Grosso do Sul, Brasil, na safra 2010/2011. Os tratamentos constaram de três híbridos de milho com diferentes arquiteturas, consorciados com três espécies forrageiras: ***Brachiaria ruziziensis***, ***B. brizantha*** *e* ***B. decumbens****, em cinco densidades, e a massa resultante foi mantida no inverno. Na estação de cultivo subsequente, as forragens foram dessecadas antes do plantio da soja, e a massa seca das forrageiras e das plantas daninhas, bem como o solo coberto por plantas daninhas e a proporção de plantas daninhas (WPI), foram determinados 15 dias após a emergência da soja. Os dados foram submetidos ao teste F e analisados por regressão ou por comparação múltipla de médias, de acordo com sua natureza. Quando o milho é consorciado com espécies de* ***Brachiaria****, problemas com plantas daninhas podem ser antecipados em áreas com espécies menos competitivas, como* ***B. ruziziensis****. Nas condições dos experimentos,* ***B. brizantha*** *e* ***B. decumbens*** *foram mais capazes de inibir a proliferação de plantas daninhas no inverno.*

Palavras-chave: ***Brachiaria***, índice de proporção de espécies, cultivo de inverno, palhada.

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[1] Recebido para publicação em 12.2.2012 e aprovado em 18.5.2012.

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INTRODUCTION

Corn is planted in the Center West region of Brazil as a second crop, between January and March, following soybeans or beans. These fields usually present low mulching in the soil during the winter due to the small amount of dry mass resulting from corn crop (Brüggemann, 2011), which favors the multiplication of weed species during this period (Oliveira Neto et al., 2010).

According to Oliveira (2001), forages of the Genus *Brachiaria* are the most used for intercropping with corn, being highlighted by its excellent adaptation to low fertility soils, easy establishment, and high production of dry mass. The intercropping of *Brachiaria* species with corn as a second crop represents an important alternative for increasing the volume of mulching in the cropping system (Ceccon et al., 2010), with no reduction in crop yield (Ceccon, 2007; Freitas et al., 2008). In fact, under certain circumstances the presence of mulching positively influences the yield potential of corn, due to temperature regulation at shallow soil depths, nitrogen fixation, enhanced soil moisture conservation, and reduction of erosion following heavy rains (Singh et al., 2011).

Infestation by weed species may be a concern in such intercropping systems if they occur at high levels, mainly due to the limitation on herbicides and doses allowed to be applied in the intercropping (Ceccon et al., 2010; Parwada & Mudimu, 2011). Thus, understanding not only the level of occurrence but also the composition of the weed community under each cropping system is important for achieving efficient control (Suresh & Reddy, 2010). Introduced intercropping species should be, by themselves, efficient in minimizing the occurrence of weed species in the intercrop, but while the presence of straw reduces the percentage of emergence of some weed species, it may increase the occurrence of others (Voll et al., 2005), mainly in terms of differential carbon metabolism (Silva et al., 2007).

This study aimed to evaluate the weeds infestation in soybeans following corn/forages intercrop, as a function of corn plant structure, forage species, and density.

MATERIAL AND METHODS

Trials were installed in two experimental areas owned by the Brazilian Agricultural Research Corporation – EMBRAPA, Western Region Agriculture Center, one of them located in Dourados (Lat -22.2844°, Lon -54.8068°, Alt 400m), and the other at Ponta Porã city (Lat -22.5489°, Lon -55.6515°, Alt 655m), state of Mato Grosso do Sul, Brazil. Soil is classified as clayey Oxisoil in both areas. The experiment was installed in a completely randomized blocks design, and plots were arranged in a split-split plot design 3x3x5, with four replications. The main plots comprised three corn hybrids, sub-plots by three *Brachiaria* species and sub-sub-plots by five populations of *Brachiaria*. Experimental plots comprised four rows of corn with 5 m long spaced in 0.9 m, intercropped with three rows of one of the *Brachiaria* species and density, according to the treatments. Both lateral corn rows, as well as 1 m at the beginning and at the end of the plot, were not considered in the evaluations.

Corn hybrids were chosen by contrasting features: AG9010 (very short cycle, upright leaves); BRS1010 (short cycle, semi-decumbent leaves) and DOW2B710 (short cycle, decumbent leaves), being planted in intercropping with populations of 0, 5, 10, 20 and 40 plants m^{-2} of *Brachiaria ruziziensis* and *B. decumbens*, or 0, 2, 4, 8 and 16 plants m^{-2} of *B. brizantha* cv. Piatã. This difference in density for Piatã is due to its known higher aggressiveness in accumulating dry mass. Planting was accomplished under the no-till system on February18 and 25, 2010, respectively, for Dourados and Ponta Porã locations, by using a pneumatic drill Semeato PAR 2800 for planting corn, and Wintersteiger Plotseed TC with adaptations, for planting the intercropped populations of forages.

Fertilization was done at the seeding furrow of corn by applying 200 kg ha^{-1} of NPK 05-20-20. Weed control was done by the application of the herbicide atrazine at a dose of 1.5 L ha^{-1} in early post-emergence of both crop and weeds. Pests were controlled with two applications of deltamethrin 10 and 30 days after emergence (DAE) of the corn at a dose of 0.005 L ha^{-1}.

Corn was harvested in August 2010 and the forages were desiccated with 1440 g a.e. ha^{-1} of glyphosate in October 2010, 14 days before planting soybeans, whose emergence occurred 7 days after planting (DAP) in both locations. Weed species emerged from the soil seed bank were evaluated 36 days after the desiccation of the forages (15 DAE of the soybean); for that, the *Random Quadrats* sampling method (Barbour et al., 1980) was used and two areas of 2,500 cm^2 in each plot were sampled. All the emerged seedlings were collected, joined by group (broadleaved or grass weeds) inside each sampling, and stored in paper bags, being dried in an oven with continuous air circulation for posterior dry mass determination. At the same time, the percentage of coverage of the area by each group of weeds was estimated by two skilled, previously trained evaluators, where zero was the complete absence of coverage, and 100 when the entire plot was covered with straw. The amount of straw left by the three species of *Brachiaria* at the soil surface was also evaluated 36 days after desiccation (15 DAE of the soybean), by collecting four sub-samples of 0.5 m x 0.5 m (1.0m^2 total) per plot.

The data from both locations were pool analyzed by the F-test, being further explored according to the significances of the interactions in the analysis of variance. The corn genotype was not significant for any of the variables studied. The dry mass of the weeds was submitted to non-linear regression analysis by location, forage species, and weed group (broadleaved of grass), at a 5% significance level; soil covered by weed species (%) of each group was analyzed as a function of forage species and density; the Weed Proportion Index [WPI=(Bw/(Bw+Gw)) was also calculated, where Bw = broadleaves and Gw = grass weeds], ranging from 0.0 (grass weeds only) to 1.0 (broadleaved weeds only) as a function of location, forage species, and its planting density.

RESULTS AND DISCUSSION

Dry mass of weed species is shown in Figure 1. In the trial at Ponta Porã it is possible to observe that the dry mass of grass weeds was relatively low even at the treatment with the absence of forages, except for the area with *B. ruziziensis*, where the infestation level of grass weeds was constant, of about 1.0 g m^{-2} of dry mass. The absence of infestation even at the checks with no forages indicates that the area at that location presents low infestation by grass species (Figure 1).

In Ponta Porã, broadleaved weeds were predominant, being able to accumulate about 5.3 g m^{-2} of dry mass in absence of forages (Figure 1). In general terms, the level of infestation decreased as a forage density of *B. ruziziensis* was increased, with about 1.7, 2.5 and 1.6 g m^{-2} of dry mass of broadleaved weeds under the highest forages densities. The infestation of broadleaved weeds under *B. brizantha* decreased to the minimum from the density of 2 plants m^{-2}, while the lower infestation under cultivation of the other two forages was reached only under the highest planting density. While 10 plants m^{-2} of *B. ruziziensis* and *B. decumbens* were able to inhibit by34.5 and 47.4%, respectively, the infestation by broadleaves, *B. brizantha* at a density of 2 plants m^{-2} was able to reduce by 41.7% the level of infestation (Figure 1).

In Dourados, the level of infestation was more balanced between grass and broadleaves, and at the highest densities, *B. ruziziensis* was able to reduce the infestations by 57.4 and 89.3%; *B. brizantha* in 75.3 and 58.0%, and *B. decumbens* in 65.4 and 93.8%, respectively, for broadleaved and grass weed species (Figure 1).

Gimenes et al. (2009) studied the incidence of *Digitaria horizontalis*, *Ipomoea grandifolia* and *Cenchrus echinatus* 30 days after intercropping corn and *B. brizantha*, at seeding rates ranging from 0 to 20 kg ha^{-1}. The authors found that infestation was reduced in all seeding densities tested, and that weed infestation of the three weed species was reduced by 92.2, 91.4 and 92.9 %,respectively, at the highest seeding rate (20 kg ha^{-1} of seeds).

As shown in Figure 1, the infestation by grass weed species in Ponta Porã was almost null, except for the treatment with *B. ruziziensis*. This resulted in stable WPI of about 0.98–1.0 at treatments with *B. brizantha* and *B. decumbens* at all densities (Figura 2), while for treatments with *B. ruziziensis*, the Kolmogorov-Smirnov (K-S) statistic indicated

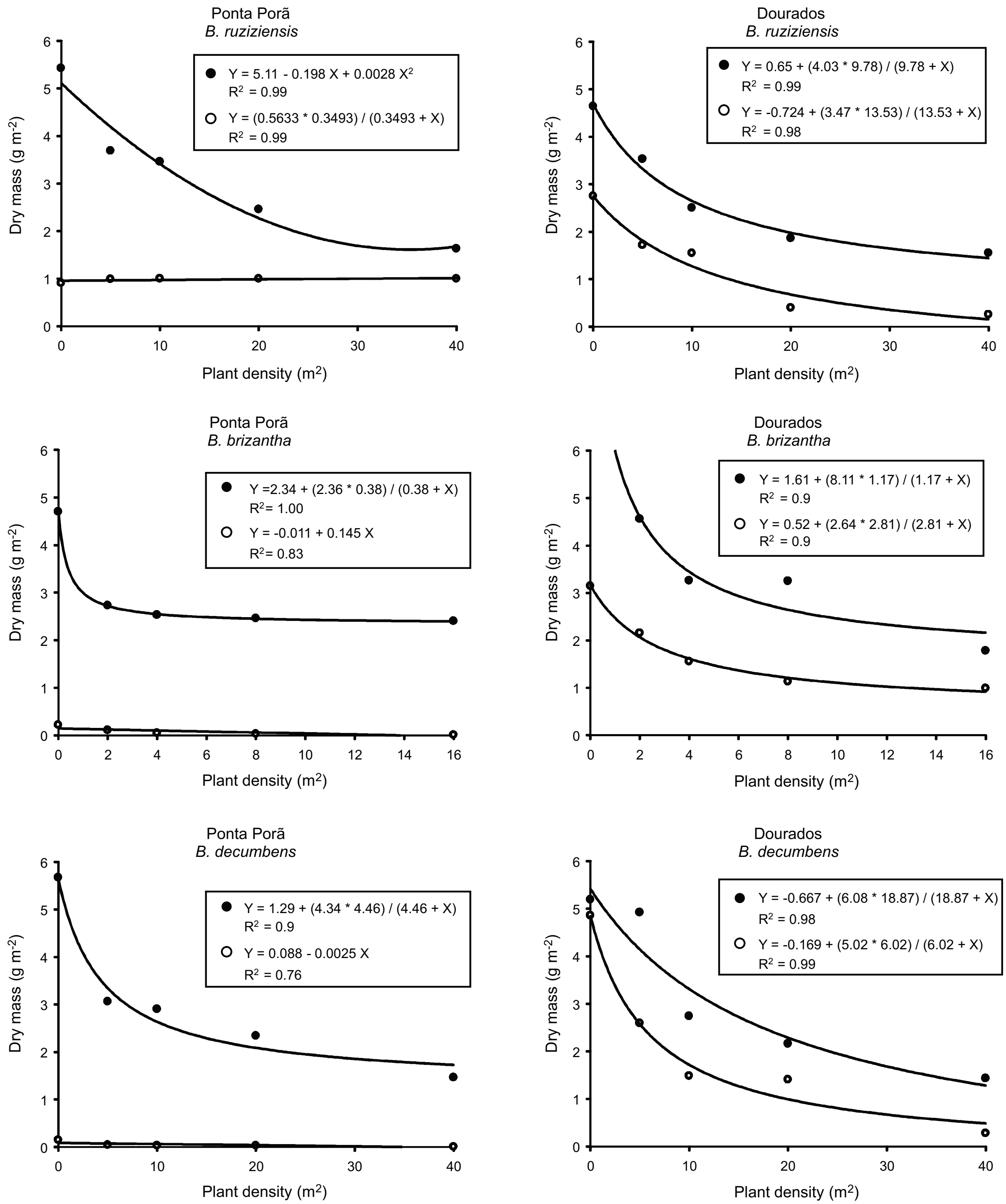

Figure 1 - Dry mass of weed species (g m^{-2}) as a function of forage planting density, location (Ponta Porã and Dourados), forage species (*B. ruziziensis*; *B. brizantha* cv. Piatã; *B. decumbens*), and plant group (● broadleaved weeds; ○ grass weeds). Embrapa Western Region Agriculture, Dourados-MS, Brazil, 2011.

an adjusted regression to data (Massey, 1951) with a WPI of 0.90 in the absence of *B. ruziziensis*, and about 0.98–1.0 for the other densities (Figure 2). Although the data indicates that the influence of forage density was almost null on the proportion of broadleaved weeds observed at the treatments in Ponta Porã, this is due to the very low occurrence of grass weeds, so the results of WPI at the location of Ponta Porã should be considered with some reservation.

On the other hand, the emergence of grass weed species in Dourados decreased (WPI increased) as the density of forages was increased (Figure 2), except for *B. brizantha* where it was constant at about 0.70 for all densities. For *B. ruziziensis*, WPI increased from 0.61 at the check to 0.80 under 40 plants m^{-2} of the forage; the same was observed for *B. decumbens*, where WPI increased from 0.47 at the check to 0.82 under 40 plants m^{-2}.

Reduction in the occurrence of weed species may be attributed to the competitive and allelopathic effects of the forage over the weed community. To cause changes in WPI, the mulching on the soil should either inhibit the germination of photoblastic positive seeds, or present an allelopathic effect on the germination of these seeds (Salvador, 2007). Such features are essential in choosing the most adequate species for intercropping when aiming at weed suppression (Gimenes et al., 2009). Borghi et al. (2008) studied crop row spacing of corn intercropped with *B. brizantha* planted at the crop row, inter-row and both, and concluded that when *B. brizantha* was drill seeded both in rows and inter-rows of the crop,

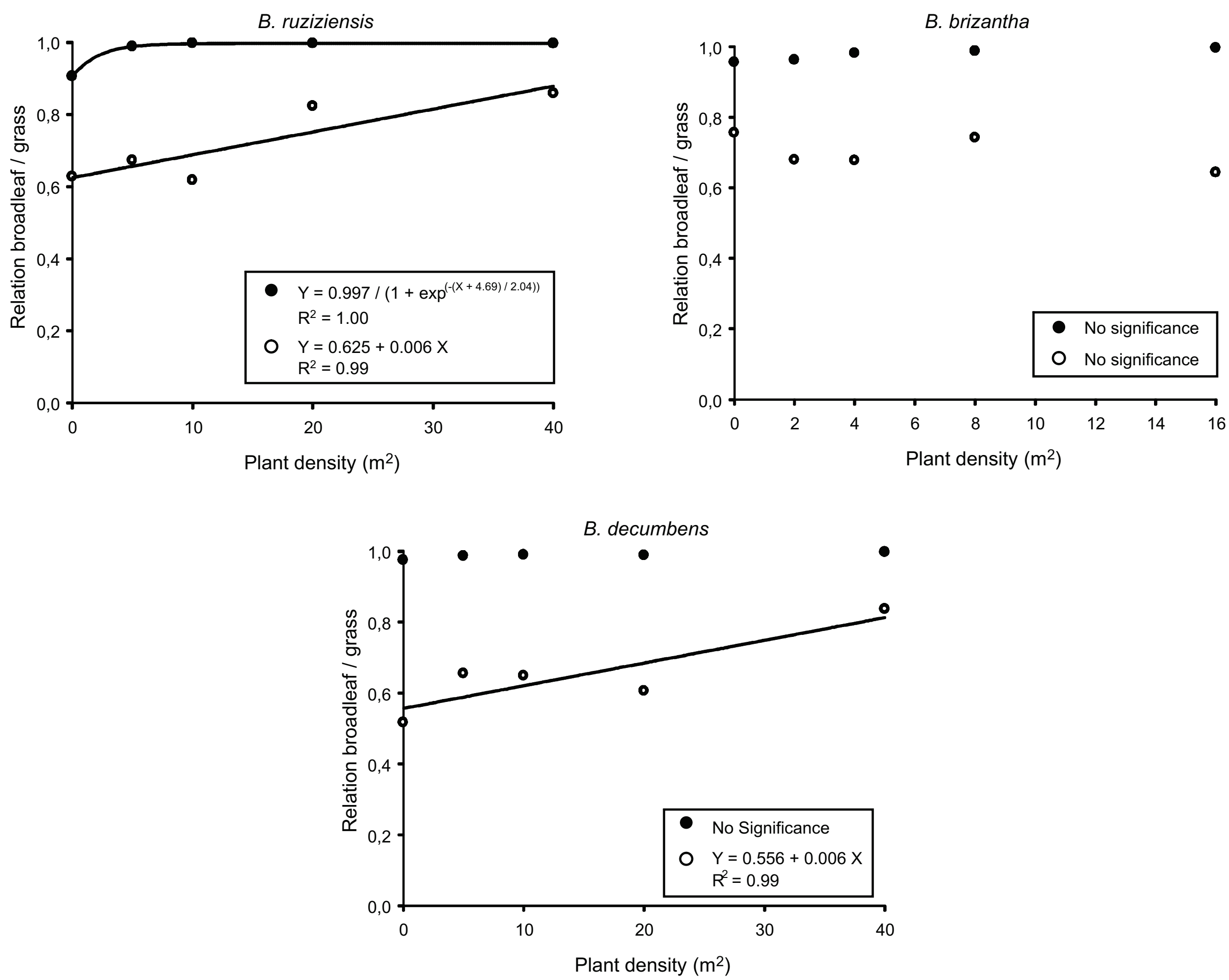

Figure 2 - Index describing the relation between Broadleaved and Grass weeds (Weed Proportion Index - WPI), as a function of species and density of the forage plants, and location of the trial. Index was arranged so that 1 = only broadleaved weeds present, and o = only grass weeds present. Locations: • Ponta Porã; o Dourados. Embrapa Western Region Agriculture, Dourados-MS, Brazil, 2011.

it was able to inhibit weeds infestation by 95%, independently of crop row spacing (45 or 90 cm).

The percentage of soil covered (SC) by each group of weed species was only significant for Ponta Porã. SC by broadleaved weeds was only influenced by the density of *B. decumbens* (Table 1), where the check presented 18.9% of the soil covered by this group of weeds; densities of 5 and 10 plants m^{-2} presented around 11.9% of the soil covered, and the two highest densities (20 and 40 plants m^{-2}) presented around 5.5% of SC% (Table 1). For *B. ruziziensis* and *B. brizantha*, SC% was not affected by the planting density (Table 1).

Grass weeds did not differ as the density of *B. decumbens* was increased (Table 1), probably due to the low infestation observed, with average SC% equal to 0.27 (Table 2). On the other hand, for treatments with *B. ruziziensis*, infestation by grasses was lower than the check from the density of 5 plants m^{-2}, and for *B. brizantha*, grass infestation was reduced only at the highest planting density (Table 1).

Gimenez et al. (2009) highlights that, from 60 DAE, *B. brizantha* planted at a density of 20 kg ha^{-1} of seeds is able to cover 100% of the available space with its canopy, allowing for the maximum suppression of weed species. The authors also highlight that *B. brizantha* was able to suppress *C. echinatus* more efficiently than *I. grandifolia*, and this is probably related to the photosynthetic physiology of these weed species: the first is a C_4 grass while the latter is a C_3-carbon fixation species. Although most efficient in water use and capable of reaching higher photosynthesis rates, the C_4 species demands more radiation to allow its positive Net Assimilation Rate (NAR), thus these species are more seriously affected by shade (Silva et al., 2007).

When SC% is analyzed independently of planting density (Table 2), *B. brizantha* and *B. decumbens* presented lower infestation by broadleaved weeds than *B. ruziziensis*, and *B. decumbens* presented lower infestation by grass weed species than *B. ruziziensis* and *B. brizantha* (Table 2). On average, *B. ruziziensis* was less efficient than the other species in inhibiting the occurrence of weed species (Table 2).

In Figure 3 the remaining amount of straw left by the species of *Brachiaria* 36 days after desiccation is shown for both locations (Ponta Porã and Dourados). In Ponta Porã, all the species were able to leave similar amounts of

Table 1 - Soil covered (%) by a group (broadleaved or grass weeds) of weed species in soybean following corn intercropped with forages, at Ponta Porã trial, as a function of forage species and planting density. Embrapa Western Region Agriculture, 2011

Forage density	Broadleaved Weeds		
	Ruziziensis	*Brizantha*	*Decumbens*
0[1/]	16.4 a[2/]	13.5 a	18.9 a
1	16.2 a	9.1 a	11.2 b
2	15.4 a	9.8 a	12.6 b
3	16.6 a	7.8 a	6.7 bc
4	10.3 a	7.1 a	4.3 c
Forage density	**Grass Weeds**		
	Ruziziensis	*Brizantha*	*Decumbens*
0[1/]	1.08 a[2/]	0.58 a	0.33 a
1	0.50 b	0.53 a	0.33 a
2	0.42 b	0.58 a	0.33 a
3	0.25 b	0.83 a	0.0 a
4	0.58 b	0.33 b	0.33 a

[1/] Densities 0, 1, 2, 3 an 4 are equivalent, respectively, to 0, 5, 10, 20 and 40 plants m^{-2} for *B.ruziziensis* and *B. decumbens*, and to 0, 2, 4, 8 and 16 plants m^{-2} for *B. Brizantha*. [2/] Means followed by the same letter, at the columns, did not differ according to the DMRT test at 5% probability.

Table 2 - Soil covered (%) by group (broadleaved or grass weeds) of weed species in soybean following corn intercropped with forages, at Ponta Porã trial, as a function of the forage species. Embrapa Western Region Agriculture, 2011

Forage Species	Broadleaves	Grasses	Total
B. ruziziensis	15.0 a[1/]	0.56 a	15.6 a
B. brizantha	9.5 b	0.53 a	10.0 b
B. decumbens	10.7 b	0.27 b	11.0 b

[1/] Means followed by the same letter, in the columns, did not differ according to the DMRT test at 5% probability.

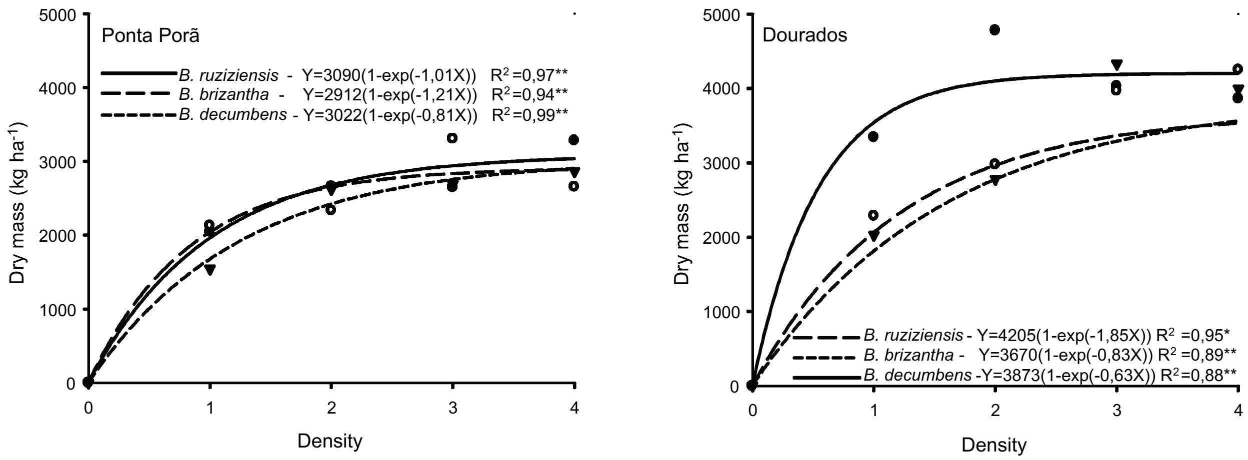

Figure 3 - Dry mass of the forage species established on the previous year intercropped with corn, at the beginning of the subsequent cropping season (October), as a function of location and forage species. Embrapa Western Region Agriculture, Dourados-MS, Brazil, 2011. Densities 0, 1, 2, 3 an 4 are equivalent, respectively, to 0, 5, 10, 20 and 40 plants m^{-2} for *B. ruziziensis* and *B. decumbens*, and to 0, 2, 4, 8 and 16 plants m^{-2} for *B. Brizantha*.

straw on the soil surface by the time of the evaluation of weeds occurrence, while in Dourados *B. ruziziensis* was able to produce higher amounts of straw in comparison to *B. brizantha* and *B. decumbens* at the lower planting densities; at higher densities the amount of straw was similar among species (Figure 3). These differences were tested according to Regazzi & Silva (2010). In addition, at the highest forage density, the absolute amount of straw deposited at the soil surface was about 3000 kg ha^{-1} in Ponta Porã and about 4000 kg ha^{-1} in Dourados (Figure 3), which could help explain the lower levels of absolute infestation in Dourados at the highest forage density in comparison to Ponta Porã (Figure 1).

Cobucci (2001) reports that, according to the optimal population for each species, forages are efficient in reducing infestation by weed species. However, even the best of the species fails in occupying all environmental niches, leaving room for more aggressive species (Gimenes et al., 2009). In this way, although forages should be used as effective tools for weed suppression, it is often necessary to use additional control techniques to avoid allowing weeds to increase their frequency in the area (Ceccon et al., 2010; Parwada & Mudimu, 2011).

The choice of the species to be intercropped with corn should rely mainly on its agronomical performance in the intercrop. When intercropping corn with *Brachiaria*, a reduction in the overall weeds infestation may always be expected; among the studied forage species, more problems with weeds may be anticipated in areas with less competitive species, like *B. ruziziensis*. Under the conditions of the trials, *B. brizantha* and *B. decumbens* were more capable of inhibiting the emergence of weed species in the winter.

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