Suppressive effects on weeds and dry matter yields of cover crops

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Abstract – The objective of this work was to evaluate the dry matter yield of cover crops and their suppressive effects on weeds. The experiment was carried out during three years in a cerrado area of the state of Goiás, Brazil, and consisted of 16 treatments with fallow and cover crops cultivated in single cropping and intercropping. Fallow allowed high weed infestation. Cover crops affected the composition of weeds, which showed greater diversity in fallow, followed by the *Pennisetum glaucum* 'BRS 1501' and *Cajanus cajan* crops. In the average of the three experimental years, the highest dry matter yield was observed for the treatments *Panicum maximum* (10,857 kg ha^{-1}), *Urochloa brizantha* 'Piatã' (11,437 kg ha^{-1}), *U. ruziziensis* (9,463 kg ha^{-1}), and *U. ruziziensis* intercropped with *Crotalaria spectabilis* (9,167 kg ha^{-1}), which prevented weed infestation. *Pennisetum glaucum* 'BRS 1501' had a low dry matter yield (<5,000 kg ha^{-1}) and did not suppress weeds. *Panicum maximum*, *U. brizantha* 'Piatã', *U. ruziziensis*, and *U. ruziziensis* intercropped with *C. spectabilis* provide high dry matter yield and suppress weed infestation in the cerrado area.

Index terms: fallow, species composition, straw mulch, weed control.

Supressão de invasoras e produtividade de matéria seca por plantas de cobertura

Resumo – O objetivo deste trabalho foi avaliar a produção de matéria seca de plantas de cobertura e seus efeitos supressivos sobre plantas daninhas. O experimento foi conduzido durante três anos em área de cerrado do Estado de Goiás e consistiu de 16 tratamentos com pousio e plantas de cobertura em cultivos solteiros e consorciados. O pousio propiciou alta infestação de plantas daninhas. As plantas de cobertura influenciaram a composição de plantas daninhas, que apresentaram maior diversidade no pousio, seguido dos cultivos de *Pennisetum glaucum* 'BRS 1501' e de *Cajanus cajan*. Na média dos três anos experimentais, as maiores produções de matéria seca foram observadas para os tratamentos *Panicum maximum* (10.857 kg ha^{-1}), *Urochloa brizantha* 'Piatã' (11.437 kg ha^{-1}), *U. ruziziensis* (9.463 kg ha^{-1}) e *U. ruziziensis* consorciada com *Crotalaria spectabilis* (9.167 kg ha^{-1}), o que impediu a infestação de plantas daninhas. *Pennisetum glaucum* 'BRS 1501' teve baixa produção de matéria seca (<5.000 kg ha^{-1}) e não suprimiu as plantas daninhas. *Panicum maximum*, *U. brizantha* 'Piatã', *U. ruziziensis* e *U. ruziziensis* consorciada com *C. spectabilis* apresentam grande produção de matéria seca e suprimem a infestação de plantas daninhas em área de cerrado.

Termos para indexação: pousio, composição de espécies, cobertura morta, controle de plantas daninhas.

Introduction

The current crop production system in the Brazilian Cerrado region is characterized by extensive cultivation, lack of irrigation, intensive mechanization, and the excessive use of fertilizers and pesticides. In this model, the herbicides are the main form of weed management.

Conventional tillage with plows and harrows is still used as a form of soil management and weed control. However, this practice favors erosion and reduces organic matter content, which is fundamental to soil quality (Scopel et al., 2013). Conservation agriculture is based on soil cover, minimal soil disturbance, i.e., no-tillage system, and crop rotation. Therefore, due to reduced tillage, cover crops can help protect soil from erosion (Scopel et al., 2013). In addition, soil cover crops and their residual dry matter also prevent the incidence and development of weeds (Didon et al., 2014; Korres & Norsworthy, 2015; Nichols et al., 2015) and may reduce the use of herbicides (Campiglia et al., 2010; Brust et al., 2014). The suppression of weed germination and establishment is attributed to light blockage, mechanical pressure, and production of allelochemicals by the high biomass produced by the cover crops (Carr et al., 2013).

The cultivation of *Pennisetum glaucum* as a cover crop in the off-season is common in the Brazilian Cerrado region, and, in some cases, species of the genus *Urochloa* are also cultivated. However, for a production system to be sustainable it is essential to include and diversify cover crops (Lin, 2011; Smith et al., 2008).

Although some studies have already shown the contribution of cover crops for weed management, it is also important to know the suppressive effect of each species. This information can be used to support subsequent weed management in the Brazilian Cerrado, in which the use of herbicides is essential, but, in some cases, excessive.

The objective of this work was to evaluate the dry matter yield of cover crops and their suppressive effects on weeds.

Materials and Methods

The experiment was conducted under rainfed conditions in the experimental fields of Fundação Goiás, located in the state of Goiás, Brazil (17º50'34"S, 50º35'58"W, at 560 m of altitude), in 2010, 2011, and 2012. The soil of the area is classified as a Latossolo Vermelho Distrófico (Santos et al., 2013), i.e., a Typic Haplorthox (Soil Survey Staff, 2014). The climate is Aw, according to Köppen-Geiger's climate classification system, with an average rainfall of less than 2,000 mm, concentrated from October to March (Figure 1).

The experiment consisted of 16 treatments with fallow and cover crops (Table 1) sown as a second crop after soybean [*Glycine max* (L.) Merr.] cultivation and harvest. The cover crops used were: *Panicum maximum* Jacq., *Urochloa brizantha* (A.Rich.) R.D.Webster 'Piatã', *Urochloa ruziziensis* (R.Germ. & C.M.Evrard) Morrone & Zuloaga, *Pennisetum glaucum* (L.) R.Br. 'BRS 1501', and *Cajanus cajan* (L.) Millsp. single cropped, as well as *U. ruziziensis* intercropped with *Sorghum bicolor* (L.) Moench, *Sesamum indicum* L., *Helianthus annuus* L., *Crotalaria spectabilis* Roth, and *Crotalaria juncea* L. The cover crops were sown at a spacing of 0.45 m between rows, except in two intercrop treatments: *H. annuus* + *U. ruziziensis* and *S. indicum* + *U. ruziziensis*, both with a distance of 0.9 m between rows. In all intercrop treatments, the cover crops were sown simultaneously at the same

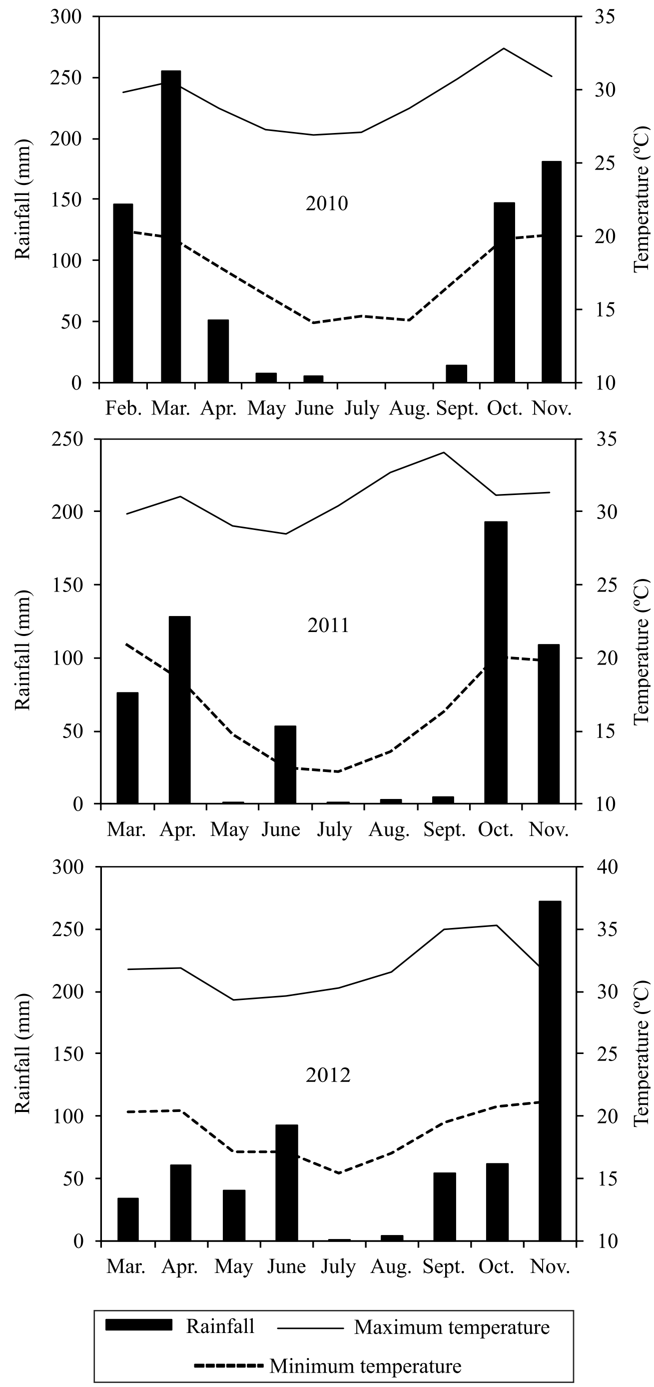

Figure 1. Monthly rainfall, and maximum and minimum air temperatures during each experimental year.

depth (2.5 cm) and in the same rows, except in two intercrop treatments: *H. annuus* + *U. ruziziensis* and *S. indicum* + *U. ruziziensis*, in which the cover crops were sown in alternate rows with a distance of 0.45 m between them.

The experimental design was a randomized complete block with four replicates. The area of each of the 64 plots was 100 m^2 (10x10 m).

After soybean harvest, the soil surface (5 cm depth) of all the experimental area was furrowed mechanically, leaving 0.45 m between rows, and cover crops were sown manually. Two days before the cover crops were sown, 400 g ha^{-1} active ingredient of paraquat were applied to control weeds and volunteer soybean plants.

The cover crops were sown on February 13 in 2010, March 18 in 2011, and March 5 in 2012. The sowing dates varied due to the early establishment of the rainy season, which affected both soybean harvest and, consequently, sowing dates. The cover crops were not fertilized or irrigated, and no method of weed control was carried out after sowing.

The dry matter of weeds and cover crops was assessed on November 23 in 2010, November 30 in 2011, and November 28 in 2012. The period between the planting of the cover crops and the evaluation of the dry matter yield of the weeds and cover crops was 283, 254, and 268 days in 2010, 2011, and 2012, respectively.

To evaluate the aboveground dry matter of the weeds, a square standard frame was used (0.5x0.5 m), being randomly released three times in each plot. The weeds found within the square frame were cut close to the ground, separated, and quantified by species. After the sampling of the weeds, 0.25 m^2 of the green shoot of the cover crops was collected three times in each plot. The cover crops and weeds were placed in separate paper bags and taken to be dried in an oven with forced air circulation, at 65°C, until reaching constant dry weight. Subsequently, the dry matter (kg ha^{-1}) of weeds (all species together) and cover crops was determined. It should be highlighted that weeds and cover crop shoots were collected in different sampling areas of

Table 1. Cover crop treatments and respective amount of pure viable seeds used.

Treatments	Pure viable seeds (kg ha^{-1})
Fallow	-
Panicum maximum	3
Urochloa brizantha 'Piatã'	5
Urochloa ruziziensis	4
Pennisetum glaucum 'BRS 1501'	12
Cajanus cajan	20
Sorghum bicolor (grain sorghum) + *Urochloa ruziziensis*	8 + 2.4
Sesamum indicum + *Urochloa ruziziensis* (alternate rows)	1.8 + 2.4
Helianthus annuus + *Urochloa ruziziensis* (alternate rows)	2.7 + 2.4
Crotalaria spectabilis + *Urochloa ruziziensis*	7 + 2.4
Crotalaria juncea + *Urochloa ruziziensis*	12 + 2.4
Pennisetum glaucum 'BRS 1501' + *Urochloa ruziziensis*	7.2 + 2.4
Cajanus cajan + *Urochloa ruziziensis*	12 + 2.4
Sorghum bicolor (forage sorghum) + *Urochloa ruziziensis*	8 + 2.4
Helianthus annuus + *Urochloa ruziziensis* (0.9 m between rows)	2.7 + 2.4
Sesamum indicum + *Urochloa ruziziensis* (0.9 m between rows)	1.8 + 2.4

the plot, except in the fallow treatment, in which only the dry matter of weeds was obtained.

In the treatments with grain and forage sorghum, *S. indicum* and *H. annuus* were mechanically harvested in the winter of each year, and the dry matter results corresponded to the straw remains of these species together with the dry matter of *U. ruziziensis*.

The data were subjected to joint and individual analyses of variance. Mean values were grouped by the Scott-Knott test, at 5% probability.

The number of weeds was determined in 36 samples from each treatment, obtained from the three samplings in each of the four replicates in the three experimental years. The weed population characteristics relative frequency, relative density, relative abundance, and the importance value index were estimated according to Mueller-Dombois & Ellenberg (1974) and Brighenti et al. (2003).

Results and Discussion

The dry matter of cover crops and weeds was affected significantly by cover crop treatments, year, and their interaction. Therefore, the results are presented separately for each year.

The aboveground dry matter of cover crops varied significantly according to the treatments. The highest yields were observed in 2010: 13,417 kg ha^{-1} for *P. maximum*, 13,333 kg ha^{-1} for *U. brizantha*, and 11,917 kg ha^{-1} for *U. ruziziensis*, which did not differ significantly from each other (Table 2). These species also produced more than 10,000 kg ha^{-1} dry matter in 2011; this result was not different from that obtained when *U. ruziziensis* was intercropped with *C. spectabilis*. In 2012, the highest dry matter yield was 9,865 kg ha^{-1} for *U. brizantha*, differing from all other treatments, except for *P. maximum*. It should be noted that high dry matter yields are fundamental for soil protection. Moreover, the family Poaceae of cover crops, due to its high C/N ratio and lignin concentration, provides a longer period with ground cover, because the straw decomposes at a slower rate (Carvalho et al, 2011).

In the three experimental years, *P. glaucum* showed low dry matter yields (Table 2), below 5,000 kg ha^{-1}, which did not differ from fallow, except in the last year. The volunteer *P. glaucum* plants also grew little during 60 days, which included the return of the rainy season and the time to evaluate dry matter. It should be pointed out that the residual dry matter of *P. glaucum* seeded from mid-February to mid-March was probably partially decomposed with increased rainfall between October and November. According to Soratto et al. (2012), in the Brazilian tropical conditions, the dry matter decomposition rate of *P. glaucum* is high, resulting in less soil protection in order to adequately meet the principles of no-tillage (Scopel et al., 2013). Single-cropped *Cajanus cajan* also did not result in high accumulation of dry matter (Table 2), producing more than 6,000 kg ha^{-1} only in 2010.

In 2010 and 2011, the dry matter yield of *U. ruziziensis*, cultivated singly, was higher than that obtained when *U. ruziziensis* was intercropped with other cover crops, except with *C. spectabilis* in 2011. In 2012, there was no difference between the dry matter of *U. ruziziensis* single cropped or intercropped (Table 2). One of the benefits of intercropping with tropical forages is the production and harvesting of grains or seeds for one species concurrently with the fodder production of *U. ruziziensis*, besides the availability of dry matter to cover and protect the soil.

In each year, the dry matter yield of the intercropping of *U. ruziziensis* with *S. indicum* did not differ between the two modes of sowing, i.e., alternating rows or the same row. This was also verified in 2011 and 2012 when *H. annuus* was intercropped with *U. ruziziensis* (Table 2); however, in 2010, the highest dry matter yield of this intercrop was achieved when sowing was done in alternate rows. Because of this condition, *U. ruziziensis* suffered less competition and presented the best conditions to develop, which increased dry matter yield and also resulted in lower weed infestation (Table 2).

The weeds identified in the experimental areas corresponded to: 11 species of dicotyledonous - *Alternanthera tenella* Colla, *Chamaesyce hirta* (L.) Millsp. (Syn. *Euphorbia hirta* L.), *Centratherum punctatum* Cass., *Sida rhombifolia* L., *Senna obtusifolia* (L.) H.S.Irwin & Barneby, *Ageratum conyzoides* L., *Amaranthus retroflexus* L., *Portulaca oleracea* L., *Galinsoga parviflora* Cav., *Bidens pilosa* L., and *Ipomoea nil* (L.) Roth; and 4 monocotyledons - *Digitaria horizontalis* Willd., *Commelina benghalensis* L., *Eleusine indica* (L.) Gaertn., and *Cyperus rotundus* L.

In 2010 and 2011, the high dry matter yield of *U. ruziziensis*, *P. maximum*, and *U. brizantha* resulted in full weed control at the time of the desiccation management (Table 2), similar to that observed in 2012 with *U. brizantha* and *P. maximum*. In the three experimental years, the vegetation formed by the association of *U. ruziziensis* with *C. spectabilis* also enabled total weed control. Cover crops affected the dry matter of weeds, as reported by Campiglia et al. (2010), Radicetti et al. (2013), Didon et al. (2014), and Dorn et al. (2015), and interfered in the weed species composition. Although the specific mechanisms of the weed control exercised by the cover crops were not the object of the present study, according to Dorn et al. (2015), competition for light, water, nutrients, and space, as well as other combined factors, must have contributed to the suppressive effect.

The species *P. maximum*, *U. brizantha*, and *U. ruziziensis*, even when sown in late summer, showed adequate growth and dry matter accumulation (Table 2). Therefore, their good soil cover due to green matter and high dry matter yield resulted in a high potential for weed control. Lemessa & Wakjira (2015) found that cover crops occupy the space and use the resources that would be available to weeds. According to Favero et al. (2001), Steckel et al. (2004), Didon et al. (2014), and Cordeau et al. (2015), cover crops contribute to weed control due to the competition for water, nutrients, and light, as well as to physical impediment. Cover crops also show allelopathic effects and reduce fluctuations in brightness, temperature, and soil moisture, factors that can interfere with the germination and emergence of weeds.

Table 2. Dry matter (kg ha^{-1}) yield of cover crops (DMCC) and weeds (DMW) arranged in 16 treatments, in three experimental years, in a cerrado area of the state of Goiás, Brazil[(1)].

Treatments	2010		2011		2012	
	DMCC	DMW	DMCC	DMW	DMCC	DMW
Fallow	0d	3,567a	0c	3,385a	0d	2.961a
Panicum maximum	13,417a	0e	11,043a	0c	8,110a	0c
Urochloa brizantha 'Piatã'	13,333a	0e	11,113a	0c	9,865a	0c
Urochloa ruziziensis	11,917a	0e	10,191a	0c	6,281b	0c
Pennisetum glaucum 'BRS 1501'	4,930d	950d	4,357c	2,868a	3,390c	1,827b
Cajanus cajan	7,467c	1,133d	5,854c	1,601b	4,848b	203c
Sorghum bicolor (grain sorghum) + *Urochloa ruziziensis*	10,350b	367e	8,981b	6c	5,846b	0c
Sesamum indicum + *Urochloa ruziziensis* (AR)	11,200b	100e	9,116b	343c	5,740b	0c
Helianthus annuus + *Urochloa ruziziensis* (AR)	10,100b	617d	7,609b	54c	6,343b	77c
Crotalaria spectabilis + *Urochloa ruziziensis*	10,533b	0e	11,007a	0c	5,960b	0c
Crotalaria juncea + *Urochloa ruziziensis*	9,633b	634d	8,163b	168c	5,462b	0c
Pennisetum glaucum 'BRS 1501' + *Urochloa ruziziensis*	10,083b	317e	7,637b	0c	4,693b	37c
Cajanus cajan + *Urochloa ruziziensis*	10,683b	33e	9,267b	0c	6,508b	0c
Sorghum bicolor (forage sorghum) + *Urochloa ruziziensis*	6,360c	1,583c	7,193b	53c	5,080b	0c
Helianthus annuus + *Urochloa ruziziensis* (DBR)	7,533c	2,167b	7,893b	0c	5,243b	0c
Sesamum indicum + *Urochloa ruziziensis* (DBR)	9,433b	533d	8,001b	100c	5,857b	0c
Mean	9,186	750	7,964	536	5,577	319
Coefficient of variation (%)	18.2	66	18.2	66	18.2	66

[(1)]Means followed by equal letters, in the columns, do not differ by the Scott-Knott test, at 5% probability. AR, alternate rows; and DBR, distance of 0.9 m between rows.

During the off-season, a high diversity of weeds was found in the fallow as a consequence of the increased weed seed bank, considering the lack of previous control. Since weed seeds are usually located in the superficial soil layers in the no-tillage system (Locke et al., 2002), cover crops help to reduce the quantity of weed seeds there (Nichols et al., 2015; Singh et al., 2015), making them an important strategy of integrated weed management. Moreover, the control exercised by cover crops can assist in the prevention and reduction in the onset of weeds resistant to glyphosate and glufosinate-ammonium herbicides. However, some cover crops were not efficient to suppress weeds. In single-cropped *P. glaucum*, there was a high incidence of weeds, resulting in 950, 2,868, and 1,827 kg ha^{-1} dry matter of weeds in 2010, 2011, and 2012, respectively (Table 2). According to Borges et al. (2014), due to its vertical growth and leaf morphology, *P. glaucum* does not promote good ground cover, and, therefore, enables weed infestation.

Cajanus cajan produced a low amount of dry matter and, when grown alone, it did not provide a fast and adequate ground cover, also enabling the development of weeds. Intercropping *C. cajan* with *U. ruziziensis* offered a better dry matter yield and soil coverage, resulting in a low incidence of weeds in 2010 (Table 2) and complete control in 2011 and 2012 with no development of weeds. The intercropping of *P. glaucum* with *U. ruziziensis* and of *C. cajan* with *U. ruziziensis*, compared with *P. glaucum* and *C. cajan* both single cropped, provided more dry matter and was also efficient in controlling weeds. The importance of *U. ruziziensis* in consortium with *P. glaucum* and *C. cajan* is directly related to its high capacity of producing dry matter and providing good ground cover, which is attributed to its prostrate growth. These characteristics are desirable in the tropical crop-livestock integration system.

In 2012, some cover crops or the mixture of some of them generated 5,000 kg ha^{-1} dry matter, which was enough to suppress weeds. However, in 2010 and 2011, this amount of dry matter was not enough for an adequate weed control. This shows that not only the amount of dry matter produced is important, as already reported by Dorn et al. (2015), but other factors are certainly fundamental, such as high quality seeds, appropriate sowing process, rapid growth, and post-seeding soil coverage.

Cover crops altered the relative frequency, relative density, and relative abundance, as well as the importance value index (IVI), of weeds (Figure 2). The greatest variety of weeds, i.e., 15 species, was observed in the fallow, followed by *P. glaucum* and *C. cajan*, with 12 species each. When *P. glaucum* was intercropped with *U. ruziziensis*, 6 weed species were identified. The same result was obtained when *U. ruziziensis* was planted with *S. indicum* in alternate rows.

The weed *C. hirta* presented high rates of relative frequency, relative density, and relative abundance, and, consequently, a high IVI (Figure 2). Compared with those of the other weeds, the IVI of *C. hirta* was the highest in 9 of 12 treatments. The species *C. punctatum*, *A. tenella*, and *D. horizontalis* also showed a higher IVI, with values greater than 40% in treatments 7, 6, and 5, respectively.

The monocotyledonous weed infestations were the lowest in all cover plants and in the fallow. *Digitaria horizontalis* had the largest relative frequency, relative density, and relative abundance, especially when *S. indicum* was intercropped with *U. ruziziensis* in the same row.

In fallow, the IVIs of the different weeds were: 69.1% for *C. hirta*, 65% for *D. horizontalis*, 53.2% for *A. tenella*, 41.8% for *C. punctatum*, and 31.6% for *E. indica*. Lower values were found for *P. oleracea* (8.5%), *A. retroflexus* (7.7%), *S. rhombifolia* (5.5%), *G. parviflora* (4.5%), *S. obtusifolia* (3.3%), *C. benghalensis* (2.9%), *I. nil* (2.9%), *B. pilosa* (1.9%), *C. rotundus* (1%), and *A. conyzoides* (1%).

In single-cropped *P. glaucum*, two species of weeds predominated, *C. hirta* and *C. punctatum*, with IVIs of 95.4 and 63.5%, respectively (Figure 2). Moreover, among the cover crops studied, *C. benghalensis* presented the highest IVI (25.2%) in *P. glaucum*. *Helianthus annuus* intercropped with *U. ruziziensis* in the same row produced higher shoot dry matter (2,567 kg ha^{-1}) than in alternate rows in 2010; this higher amount of dry matter decreased weed incidence (Table 2).

In order to minimize weed incidence, it is important to choose a cover crop that produces a great amount of biomass in a short period of time. Due to their high dry matter yield, *P. maximum*, *U. brizantha*, and *U. ruziziensis* are an important component of integrated weed management in no-tillage cropping systems in the Brazilian Cerrado region.

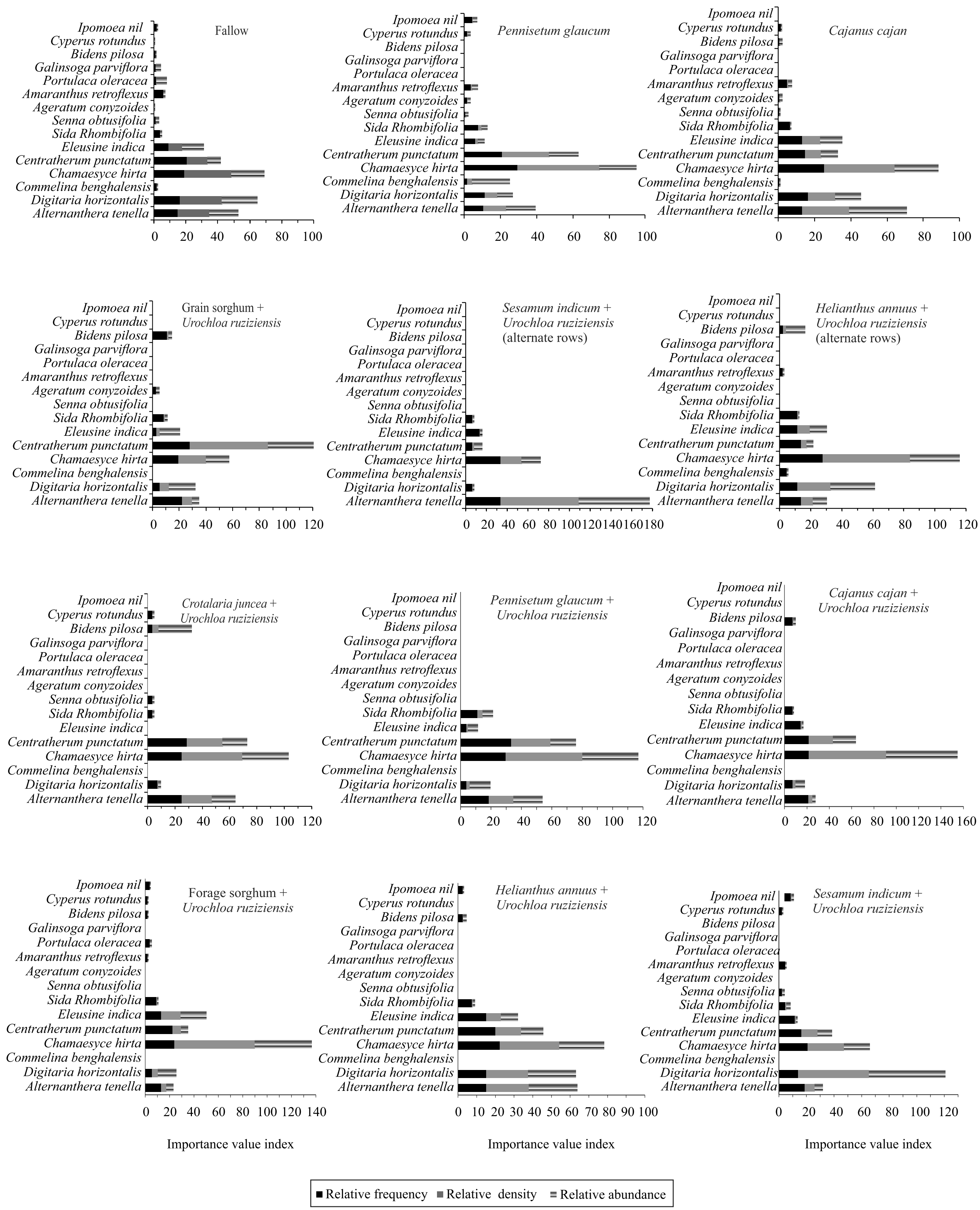

Figure 2. Phytosociological indices of weeds in the cover crops and in the fallow.

Conclusions

1. The species *Pennisetum glaucum* 'BRS 1501' has low dry matter yield and does not suppress weeds.

2. *Panicum maximum*, *Urochloa brizantha*, *Urochloa ruziziensis*, and *U. ruziziensis* intercropped with *Crotalaria spectabilis* provide high dry matter yield and prevent weed infestation.

3. Cover crops affect the weed community, and *P. glaucum* and *Cajanus cajan* enable a greater variability of weed species.

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