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COVER CROPS IN THE OFF-SEASON IN THE WEED MANAGEMENT AT NO-TILLAGE AREA[1]

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ABSTRACT - Cover crops can provide suppression of weeds and together with chemical control make the proper management of weeds in agricultural areas. The objective of this study was to evaluate the effect of cover crop cultivation during the off-season on weed development in a no-tillage area. The experimental design was in randomized blocks scheme with six treatments and four replications. The treatments were: fallow (control), millet (*Pennisetum glaucum*) + crotalaria (*Crotalaria spectabilis* + *C. juncea* + *C. ochroleuca*), millet + pigeon pea (*Cajanus cajans*), millet + *Urochloa ruziziensis*, millet + *Urochloa ruziziensis* + pigeon pea and millet + buckwheat (*Fagopyrum esculentum*. The evaluations were done at 30, 75 and 225 days after sowing of the cover crops (DAS). The main growth weed species in the area were *Cenchrus echinathus*, *Euphorbia heterophylla* and *Digitaria insularis*. Fallow treatment showed greater number of weed species with density of 184 plants m^{-2}, 9.0 species and with 527.8 g m^{-2} of dry matter mass at 225 DAS. In all treatments verified reduction in the density and mass of weeds dry matter compared to the fallow, with average of 30 plants m^{-2}, 5.8 species and 7.9 g m^{-2} at 225 DAS, respectively. The use of cover crops is an important strategy for weed control in agricultural areas.

Keywords: Weeds. Phytosociological survey. Integrated management. Cultural control. Sustainable management.

PLANTAS DE COBERTURA NA ENTRESSAFRA NO MANEJO DE PLANTAS DANINHAS EM ÁREA DE PLANTIO DIRETO

RESUMO - Plantas de cobertura podem proporcionar supressão de plantas daninhas e juntamente com o controle químico compor o manejo adequado de plantas daninhas nas áreas agrícolas. O objetivo deste trabalho foi determinar o efeito do cultivo de plantas de cobertura durante a entressafra sobre o desenvolvimento de plantas daninhas em área de plantio direto. O delineamento experimental foi em blocos casualizados, com seis tratamentos e quatro repetições. Os tratamentos foram compostos das seguintes coberturas vegetais: 1. pousio (testemunha), 2. milheto (*Pennisetum glaucum*) + crotalárias (*Crotalaria spectabilis* + *C. juncea* + *C. ochroleuca*), 3. milheto + feijão-guandu (*Cajanus cajans*), 4. milheto + *Urochloa ruziziensis*, 5. milheto + *Urochloa ruziziensis* + feijão-guandu e 6. milheto + trigo mourisco (*Fagopyrum esculentum*). As avaliações foram realizadas aos 30, 75 e 225 dias após a semeadura (DAS) das plantas de cobertura. As principais plantas daninhas na área foram *Cenchrus echinathus*, *Euphorbia heterophylla* e *Digitaria insularis*. A área de pousio apresentou a maior quantidade, número de espécies e produção de matéria seca de plantas daninhas com densidade de 184 plantas m^{-2}, 9,0 espécies e 527,8 g m^{-2} de matéria seca aos 225 DAS. Em todos os tratamentos com plantas de cobertura constatou-se que reduziu a densidade e a massa seca das plantas daninhas em comparação com o pousio, com média de 30 plantas m^{-2}, 5,8 espécies m^{-1} e 7,9 g m^{-2} aos 225 DAS, respectivamente. Constata-se que o uso de plantas de cobertura é importante estratégia para o controle de plantas daninhas nas áreas agrícolas.

Palavras-chave: Plantas infestantes. Levantamento fitossociológico. Manejo integrado. Controle cultural. Manejo sustentável.

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INTRODUCTION

The no-tillage system was designed using good land use practices, including minimal soil tillage, crop rotation and soil covered by the use of soil cover plants in periods without commercial crop (NASCENTE; STONE, 2018). Coverage plants, in addition to protecting the soil against solar radiation, dissipate the impact energy of raindrops, contributing to the reduction of erosion, reducing water evaporation, increasing the efficiency of nutrient cycling, and also helping to weed control, reducing infestation in the cultivation of commercial crops (WITTER et al., 2019; TROYJACK et al., 2019; MIRANDA et al., 2020; AMORIM et al., 2020; SILVA et al., 2020), thus allowing commercial culture to start its development with less competition for weeds, in addition to assisting in chemical control (FORTE et al., 2018).

One of the main options available within an integrated weed management system, especially as difficult to control, is the cultivation of cover plants during the off-season (autumn/winter), complemented by chemical management with herbicides (VARGAS; PASSOS; KARAM, 2018). In this way, these cover plants have a suppressive effect on an weed and their straw also assists in the control and reduction of weed biomass production at the beginning of crop development (WERLANG et al., 2018).

The reduction of the emergence and establishment of weeds in the area occurs due to physical impediment and also to the chemical and/or allelopathic effect (VARGAS; PASSOS; KARAM, 2018; STURM; PETEINATOS; GERHARDS, 2018; NAWAZ et al., 2020). According to Schmidt, Junge and Finckh (2019), the use of cover crops can suppress the weed seed bank in the soil, making it an important practice to be adopted in integrated weed management. The cultivation of cover crops can also stimulate the development of endophytic fungi capable of attacking weed seeds in the soil (VOLL et al., 2004) and provide an increase in population of seed predatory insects, which contribute to the reduction of certain species weeds (COSTA et al., 2018).

In this sense, the use of other management techniques can improve weed control and minimize the effects of selection pressure caused by the intensive use of chemical management year after year (CESCO et al., 2019). The management of weeds, during the off-season, is essential to avoid their development, flowering and dispersion of seeds in agricultural areas (GIRALDELI et al., 2018).

However, despite the importance of using cover crops in the management of weeds, there are still few studies that evaluate this practice, especially when using cover crop mix. Sustainable agricultural management practices are important to reduce the environmental impact and costs of food production. Thus, the knowledge of the likely effects of the practice of using cover crops in the off season, on the development of weeds can be important information in the definition of an efficient integrated management of weeds in agricultural areas, reconciling with chemical management and may allow its best use in no-tillage system under the conditions of the Brazilian Cerrado.

Thus, the objective of this work was to determine the effect of the cultivation of cover crops during the off-season in the suppression of weeds in no-till area.

MATERIAL AND METHODS

The experiment was carried out in a no-tillage area under rainfed conditions at the Capivara Farm of Embrapa Arroz e Feijão, in the municipality of Santo Antônio de Goiás / GO, located at 16° 29'47”south latitude, 49°17'20” west longitude and 805 m altitude, between the months of february and november 2018. The soil of the place is classified as Dystrophic Red Latosol (SANTOS et al., 2018), with the following chemical and physical attributes in the implementation of the experiment : pH (H_2O) = 6,0; Ca ($mmol_c\ dm^{-3}$) = 25,2; Mg ($mmol_c\ dm^{-3}$) = 10,5; P (Mehlich) ($mg\ dm^{-3}$) = 9,0; K ($mg\ dm^{-3}$) = 137; Organic Matter ($g\ dm^{-3}$) = 33,85; sand ($g\ kg^{-1}$) = 342; silt ($g\ kg^{-1}$) = 164, and clay ($g\ kg^{-1}$) = 494, with a clay texture. The region's climate is tropical in Savannah, according to the Köppen classification. Thus, there are two well-defined seasons, usually dry from may to september (autumn/winter) and rainy from october to april (spring/summer), the average annual rainfall is between 1,500 to 1,700 mm. The average annual temperature is 22.7°C, varying annually from 14.2°C to 34.8°C. Additionally, the daily data referring to the maximum, average and minimum temperatures and precipitation during the conduct of the experiment were monitored (Figure 1).

The experimental design was a randomized block with six treatments and four replications. The treatments were six vegetable coverings, being: 1. Fallow (control); 2. millet (*Pennisetum glaucum*) and crotalaria (*Crotalaria juncea*, *C. spectabilis* and *C. ochroleuca*); 3. millet and pigeon pea (*Cajanus cajan*); 4. millet and *Urochoa ruziziensis*; 5. millet, *U. ruziziensis* and pigeon pea; and 6. millet and buckwheat (*Fagopyrum esculentum*). The plots had a dimension of 5.40 m x 10 m in length, with 0.50 m being neglected on each side.

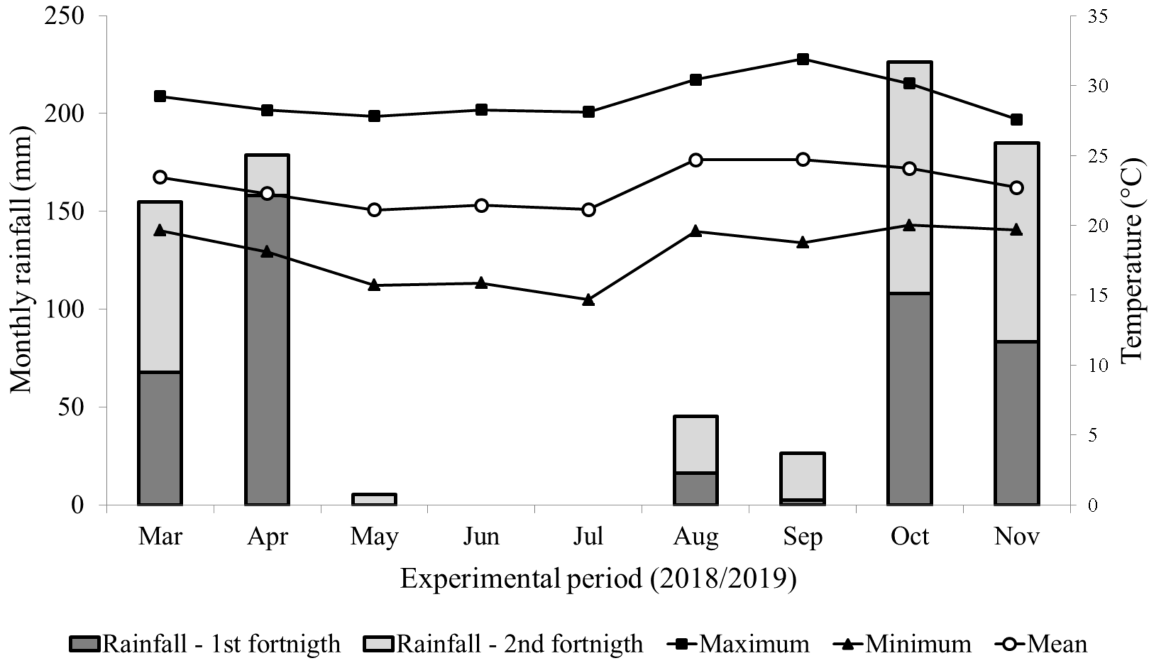

Figure 1. Air temperatures and precipitation in Santo Antônio de Goiás, during the experiment (march to november 2018).

The area was desiccated in the pre-sowing of the cover plants with a spray of glyphosate 4 L ha^{-1} (Roundup Original®, 1,440 g a.e. ha^{-1}). The cover crops were sown on 12/03/2018 under no-tillage system, after soybean cultivation in the first harvest, using 150 kg ha^{-1} of simple superphosphate, also fertilizing the fallow area. Mechanized seeding was used with a spacing of 0.45 m between the lines at a depth of 2 cm.

Weed infestation evaluations were carried out before the area was closed (30 days after the sowing of the cover plants, DAS), after the complete vegetative development of the cover plants (75 DAS) and before desiccation for sowing of the crop subsequent summer (225 DAS). For this, a hollow metallic square with an area of 0.45 m^2 was used, randomly played in four points per plot. In this square, the aerial part of all weeds was collected, taken to the laboratory, identified at the species level according to Lorenzi (2014) and separated to determine the density of weeds m^{-2} and, later, they were dried in a greenhouse forced air circulation, at 65°C for 72 hours, until constant mass, to determine the dry matter mass of the aerial part per plot.

The data of total weed infestation in the area were submitted to deviance analysis using a generalized linear Poisson model (LM) and the treatments were compared from 95% confidence intervals with Poisson distribution. The density data of the main weed plants (WP), were submitted to deviance analysis from a generalized binomial LM. The treatments were compared from 95% confidence intervals for the proportion of each weed species. The weed dry mass data were subjected to analysis of variance with plots subdivided over time and Fisher's LSD test for comparisons between the averages at 5% probability. The analyzes were performed using software R version 3.5.0 (R CORE TEAM, 2017).

RESULTS AND DISCUSSION

The most frequent weeds in the area were southern sandspur (*Cenchrus echinatus*), milkweed (*Euphorbia heterophylla*) and bitter grass (*Digitaria insularis*), with *C. echinathus* representing 80% of the total weed density in the areas fallow at 75 days after sowing cover crops (DAS). With lower densities, the occurrence of *Acanthospermum hispidum, Macroptilium martii, Amaranthus espinosus, Commelina benghalensis, Eleusine indica, Bidens pilosa, Euphorbia hirta, Cyperus rotundus, Conyza bonariensis, Borreria densiflora*, *Ipomoea* spp. and *Leonurus sibiricus*. Weeds compete for water, light and nutrients reducing crop development and can also act as hosts for pests and diseases, cause allelopathic effects, hinder harvesting and reduce land value (GALON et al., 2018). In addition, *C. echinatus* seeds can be easily fixed, as in cotton fibers, reducing their quality and price (SILVA et al., 2015) and the weeds *E. heterophylla* and *D. insularis* are species resistant to herbicides in Brazil (HEAP, 2019), which requires greater care in its control, since high densities of *D. insularis* plants reduce soybean productivity by up to 2,000 kg ha^{-1} (GAZZIERO et al., 2019).

The different combinations of cover crops, grown during the off-season of grain crops in no-tillage areas, had a positive effect on the suppression of weeds at all times of assessment in relation to fallow in terms of weed density and diversity (Table 1). At 30 days after the sowing of cover crops (DAS), all cover plants significantly reduced the weed density in the area compared to the fallow area (169 plants m^{-2}), with densities ranging between 28 and 56 plants m^{-2} (Figure 2). The consortia between millet and buckwheat and between millet and brachiaria ruziziensis provided the lowest weed densities at this time, with 28 and 31 plants m^{-2} respectively, probably due to the rapid initial development of these plants and closure of the area (NASCENTE; STONE, 2018).

At the same time (30 DAS), the occurrence of *C. echinatus* predominated in the fallow area, representing 69% of the total weeds, similarly also in the areas of the consortium millet, ruziziensis and pigeon pea and millet and crotalaria, representing 59 % and 52% of the total, respectively. On the other hand, the density of the *E. heterophylla* dicot was similar to *C. echinatus* in the other treatments (Figure 3).

Table 1. Dry matter of the aerial part of the weeds (g m^{-2}) affected by vegetation cover grown in the off-season, in three evaluations, at 30 days after sowing (DAS), 75 DAS and 225 DAS of the cover plants

Treatments[1]	Dry matter (g m^{-2})		
	30 DAS	75 DAS	225 DAS
1. Fallow (control)	35.41 aB	502.00 aA	527.82 aA
2. Millet + crotalaria	4.84 bA	7.70 bA	20.81 bA
3. Millet + pigeon pea	3.40 bA	4.55 bA	7.87 bA
4. Millet + *Urochloa ruziziensis*	3.02 bA	2.77 bA	0.23 bA
5. Millet + *Urochloa ruziziensis* + pigeon pea	2.40 bA	1.07 bA	0.32 bA
6. Millet + buckwheat	4.15 bA	11.10 bA	10.07 bA
Coefficient of variation (CV %)	39.37	24.69	36.43

Averages followed by the same letter, lower case in the column and upper case in the line, do not differ by Fisher's LSD test at 5% significance. The *p* values of the interaction between treatments and the interaction between treatments and time of evaluation were <0.001. [1] 1. fallow (control), 2. millet (*Pennisetum glaucum*) + crotalaria (*Crotalaria spectabilis* + *C. juncea* + *C. ochroleuca*), 3. millet + pigeon pea (*Cajanus cajans*), 4. millet + *Urochloa ruziziensis*, 5. millet + *Urochloa ruziziensis* + pigeon pea and 6. millet + buckwheat (*Fagopyrum esculentum*).

At 75 DAS, there was also a greater weed density in the fallow área (control), with 191 plants m^{-2} (Figure 2), 80% of *C. echinathus* (Figure 3). There was no significant difference in weed density in other treatments, varying between 11 and 24 plants m^{-2}, with the predominance of *C. echinathus and E. heterophylla*. The cover plants reached the end of vegetative development and the beginning of fruiting at this time, demonstrating high efficiency in suppressing and reducing the density of weeds in the area, due to its high biomass production capacity, reaching yields above 11 Mg ha^{-1} of dry matter of the aerial part (NASCENTE; CRUSCIOL; COBUCCI, 2013).

Also at 225 DAS, there was a greater weed density in the fallow area, with 184 plants m^{-2} (Figure 2), with a predominance of *C. echinathus* (71% of the total) (Figure 3). The treatments of the intercropping between millet and *U. ruziziensis* and between millet, *U. ruziziensis* and pigeon pea provided the lowest weed densities at this time, with 4 and 5 plants m^{-2}, respectively, due to the high vegetative vigor and biomass production of the *U. brachiaria*, which has a perennial habit and remains in the area after the beginning of millet decomposition (NASCENTE; STONE, 2018) and with greater competitive power due to its C4 metabolism in relation to pigeonpea, a C3 plant (TAIZ et al., 2014). Weed suppression is directly linked to vegetation cover provided by cover plants (FORTE et al., 2018).

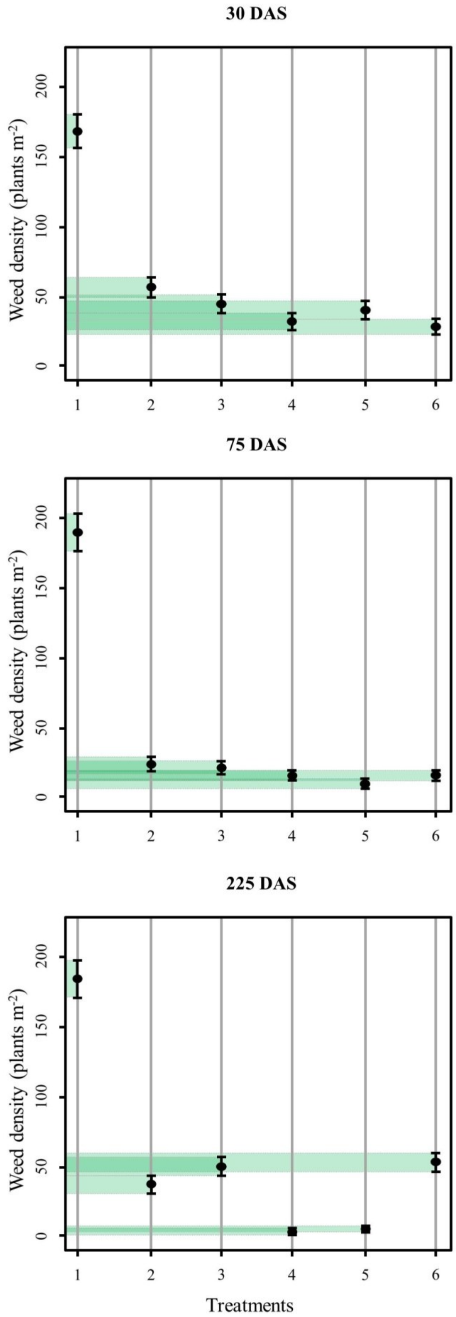

Figure 2. 95% safety intervals for the total weed population (plants m^{-2}) in the experimental area in three evaluation periods, at 30, 75 and 225 days after the sowing of cover plants (DAS). Treatments: 1. fallow (control), 2. millet (*Pennisetum glaucum*) + crotalaria (*Crotalaria spectabilis* + *C. juncea* + *C. ochroleuca*), 3. millet + pigeon pea (*Cajanus cajans*), 4. millet + *Urochloa ruziziensis*, 5. millet + *Urochloa ruziziensis* + pigeon peas and 6. millet + buckwheat (*Fagopyrum esculentum*).

The results obtained in the present work show the relevant possibility of using cover plants to help control weeds that are difficult to control. Even at lower densities, the occurrence of *E. heterophylla* and *D. insularis* in fallow areas, can become difficult to chemical control in the pre-sowing of the first crop, when they are flowering and perennialized (GUIMARÃES et al., 2019). There are records in Brazil of multiple resistance of *E. heterophylla* to acetolactate synthase (ALS) and protoporphyrinogen oxidase (PPO) inhibitors since 2004 and resistance of *D. insularis* to the herbicide glyphosate, EPSPs inhibitor, since 2008 (HEAP, 2019). In addition, remaining plants can spread the seeds and infest the entire area. Therefore, it is necessary to develop strategies that combine the use of different herbicide molecules with cover plants for the adequate control of these weeds in agricultural areas. In this sense, all treatments with cover plants were efficient to provide the absence of *D. insularis* in the area, at the time of desiccation in pre-sowing of the first harvest (Figure 3).

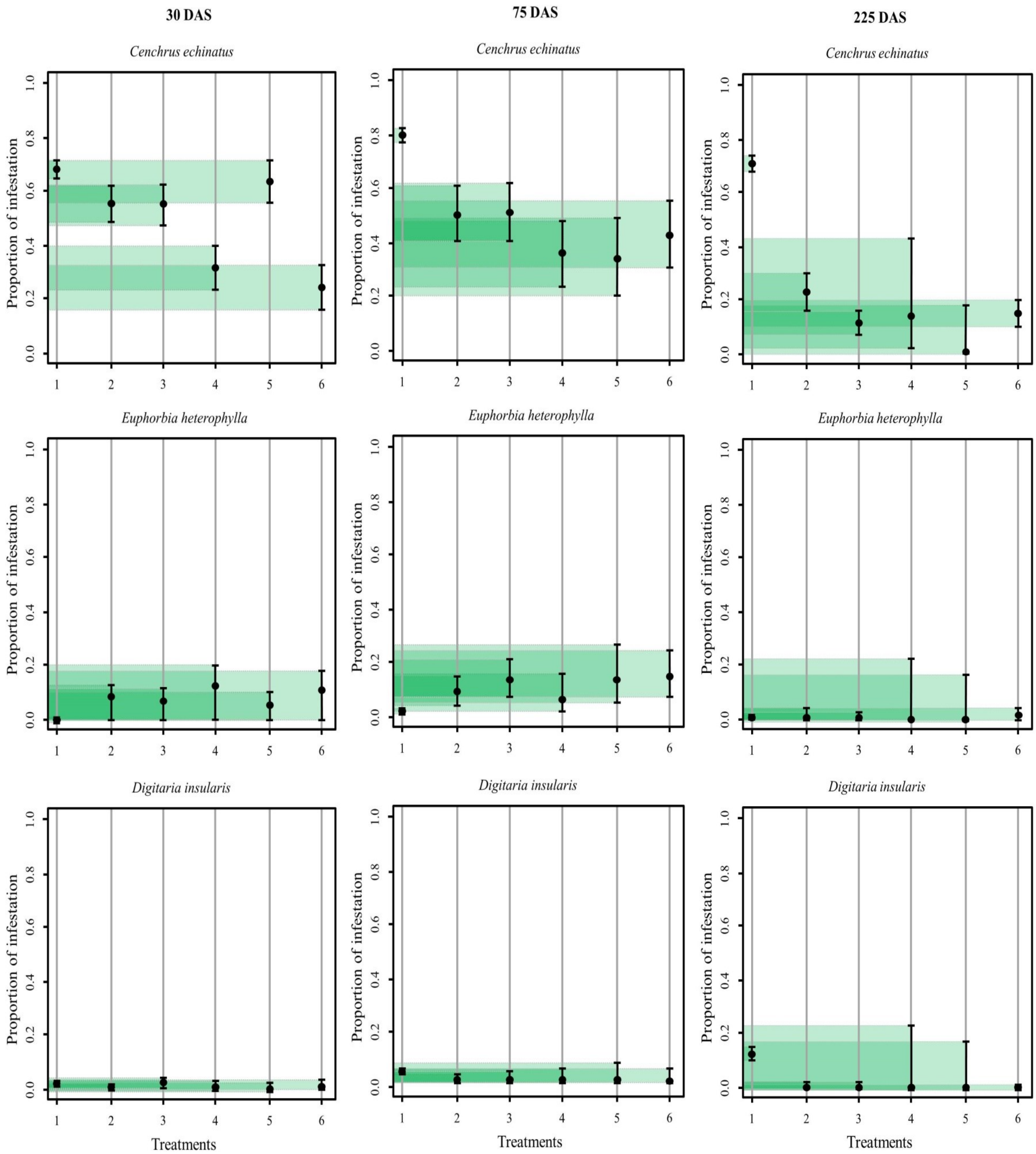

Figure 3. 95% safety intervals for the densities of *Cenchrus echinathus*, *Euphorbia heterophylla* and *Digitaria insularis* at 30 days after sowing (DAS), 75 DAS and 225 DAS of cover plants. Treatments: 1. fallow (control), 2. millet (*Pennisetum glaucum*) + crotalaria (*Crotalaria spectabilis* + *C. juncea* + *C. ochroleuca*), 3. millet + pigeon pea (*Cajanus cajans*), 4. millet + *Urochloa ruziziensis*, 5. millet + *Urochloa ruziziensis* + pigeon pea and 6. millet + buckwheat (*Fagopyrum esculentum*).

All treatments provided a reduction in the dry matter mass production of the aerial part of the weeds in comparison with the fallow, in all periods of evaluation (Table 1). The dry mass of weeds in the fallow area increased from 35 g m^{-2} at 30 DAS to 502 g m^{-2} and 528 g m^{-2} at 75 DAS and 225 DAS, respectively, and differed from areas cultivated with coverage at different times of evaluation, which averages 5.6 g m^{-2}. This shows that, in addition to presenting greater density, in the fallow area as weeds also dissipate more developed, as they did not suffer any competition for water, light and nutrients or any other growth factor, as occurred in the areas with cover plants. Thus, these weeds existing in fallow treatment have the potential to arrive at the time of desiccation for sowing the summer crop, with greater development, greater quantities of reserves and less susceptibility to the management herbicide, than those that emerged in areas cultivated with cover plants. Cesco et al. (2019) reinforce the importance of avoiding or minimizing the development of *Conyza* spp., Due to its difficult control when fully developed, even with sequential applications or with herbicide associations, cover crops being an important tool for management, and Guimarães et al. (2019) recommended the association of other control methods with the chemical for effective management of *D. insularis*.

The data found in the present study demonstrated the importance of using cover plants to suppress weeds in no-till during the off-season. In the pre-sowing of the summer crop, at 225 DAS, the weed density was reduced by an average of 83.7% (Figure 2) and the dry biomass of the weeds was reduced by an average of 98.5% in relation to fallow (Table 1). This effect was due to the greater competitiveness of cover plants, with rapid initial development, causing the closure of the area and reduced brightness on the weeds (FORTE et al., 2018). Pacheco et al. (2011) observed that millet showed the maximum production of dry matter at 60 DAS (8.5 Mg ha^{-1}) and the brachiaria ruziziensis, as a perennial plant, maintained high production of dry matter from 75 DAS, with productions above 5 Mg ha^{-1}. These results corroborate with Cornelius and Bradley (2017), who found that the cultivation of rye with cereals and rye with vetch in the fall reduced the emergence of annual weed species by 99% during winter.

Due to the lack of more work on phytosociological surveys on cover crops, these results are of great relevance for the integrated management of weeds in no-tilled areas. The cultivation of cover crops in the off-season, with a known cycle and phenological characteristics, facilitates their mechanical or chemical control in the pre-sowing of the first crop. In addition, this cultural control reduces the weed seed bank in the area and the straw on the soil provides a physical barrier, in addition to chemical or allelopathic effects, against the incidence of light and the emergence of weeds during the development of the crop (VARGAS; PASSOS; KARAM, 2018; STURM; PETEINATOS; GERHARDS, 2018). Additionally, the presence of cover plants in agricultural areas can provide other benefits to the system, such as protection against the impact of raindrop and consequently less susceptibility to erosion, increases in nutrient and organic matter contents, among others.

Thus, the use of weeds in the off-season presents itself as an efficient strategy in the management of weeds, especially those that are difficult to control. In addition to reducing the economic damage caused by the weed competition with the crops of interest, studies like this contribute to the establishment of efficient weed management in crops, in addition to isolated chemical control, increasing environmental sustainability and food security.

CONCLUSION

It is concluded that the cultivation of cover plants during the off-season of grain production provided the suppression of weeds after 30 DAS, with a reduction of 83.7% in density and 98.5% in the production of matter weed drought in relation to fallow (control) at 225 DAS and that the combination of cover plants Millet and *U. ruziziensis* and the mixture of Millet, *U. ruziziensis* and pigeon pea showed the greatest suppression of weeds at 225 DAS.

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