Growth suppression of sandspur grass by cover crops[1]

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ABSTRACT

Sandspur grass has hindered the integrated weed management in the Brazilian crop systems. This study aimed at evaluating the efficiency of biomass levels of different cover crops on the soil surface to control the sandspur grass. A complete randomized blocks design with four replications, in a 6 x 5 + 1 factorial arrangement, was used. The first factor consisted of six cover crops (*Pennisetum glaucum* - ADR 7010 and ADR 300 cultivars, *Crotalaria ochroleuca*, *Urochloa ruziziensis*, *Fagopyrum tataricum* and *Crambe abyssinica*) and the second one consisted of five biomass levels of each species (2 t ha^{-1}, 4 t ha^{-1}, 8 t ha^{-1}, 12 t ha^{-1} and 16 t ha^{-1}), plus a control treatment without soil cover. The variables analyzed were the total number of emerged plants, germination speed index, leaf area, root volume and shoot and root dry biomass. *U. ruziziensis* excelled in the suppression of *C. echinatus* growth by reducing the number of emerged plants, emergence speed index, shoot and root dry biomass, root volume and leaf area.

KEY-WORDS: *Cenchrus echinatus* L.; allelopathy; weed.

RESUMO

Supressão ao desenvolvimento de capim timbête com plantas de cobertura

O capim timbête (*Cenchrus echinatus* L.) tem dificultado o manejo integrado de plantas daninhas, nos sistemas de produção agrícola brasileiros. Este estudo objetivou avaliar a eficiência de níveis de biomassa de diferentes plantas de cobertura sobre a superfície do solo, no controle do capim timbête. O delineamento utilizado foi o de blocos ao acaso, com quatro repetições, em esquema fatorial 6 x 5 + 1. O primeiro fator foi constituído por seis espécies de cobertura (*Pennisetum glaucum* - cultivares ADR 7010 e ADR 300, *Crotalaria ochroleuca*, *Urochloa ruziziensis*, *Fagopyrum tataricum* e *Crambe abyssinica*) e o segundo por cinco níveis de biomassa de cada espécie (2 t ha^{-1}, 4 t ha^{-1}, 8 t ha^{-1}, 12 t ha^{-1} e 16 t ha^{-1}), mais um tratamento controle, sem cobertura de solo. As variáveis analisadas foram o número total de plantas emergidas, índice de velocidade de germinação, área foliar, volume de raízes e biomassa seca da parte aérea e raízes. A espécie *U. ruziziensis* destacou-se na supressão ao desenvolvimento de *C. echinatus*, por proporcionar redução no número de plantas emergidas, índice de velocidade de emergência, biomassa seca da parte aérea e raízes, volume radicular e área foliar.

PALAVRAS-CHAVE: *Cenchrus echinatus* L.; alelopatia; planta daninha.

INTRODUCTION

The search for cultivation techniques that offer higher yields and profitability, and that mitigate negative effects to the environment, are the main goals of agronomic research.

The no-tillage system with beneficial cover crops promotes increased levels of soil organic matter (Loss et al. 2011, Silva et al. 2011) and reduces soil disturbance and erosion (Vasconcelos et al. 2010). Moreover, the presence of biomass on the soil surface has potential to assist in the integrated management of weeds (Silva et al. 2009, Moraes et al. 2011, Borges et al. 2014), due to the interception of solar radiation (Duarte et al. 2007) and release of allelopathic compounds, during the mineralization process of plant residues (Theisen et al. 2000).

Weeds management in agricultural areas has been mainly sustained by chemical control. With Roundup Ready® technology, farmers intensified

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the use of glyphosate, due to easy application, effective desiccation of weeds and post-emergence management of crops. However, the use of techniques that may improve the integrated weed management is essential to minimize the effects of selection pressure caused by the intensive use of the same active ingredient (Christoffoleti & López 2003).

Cenchrus echinatus L. is a Poaceae, popularly known as sandspur grass, that is widespread in almost all cropping regions of Brazil. This species may develop in different soil fertility conditions and maintains high growth rates, even under environmental stress conditions. It has been found infesting various commercial crop fields, such as peanut, citrus, bean, cassava, soybean, sugarcane, mint, onion and tomatoe, as well as in pastures (Kissmann & Groth 1999, Duarte et al. 2007). In crops such as cotton, it is particularly important, because *C. echinatus* seeds may fixate on the cotton fibers, causing significant reduction in quality and price (Lorenzi 2000).

The response to the use of cover crops on the germination of weed plants depends on the amount and distribution of the residue, as well as its allelopathic potential (Rice 1984, Chauhan et al. 2012). The allelopathic activity of mulch on weeds depends directly on the amount of biomass, soil type, microbial population, climatic conditions and composition of the weed community species (Monqueiro et al. 2009).

Sustainable practices of agricultural management are important to reduce the environmental costs of food production. Thus, this study aimed at evaluating the efficiency of biomass levels of different cover crops to control the sandspur grass (*Cenchrus echinatus* L.) weed.

MATERIAL AND METHODS

The experiment was conducted in a greenhouse at the Universidade Federal do Piauí (UFPI), in Bom Jesus, Piauí State, Brazil, from March to June 2013.

A complete randomized blocks design with four replications, in a 6 x 5 + 1 factorial arrangement, was used. The first factor consisted of six cover crops [millet (*Penissetum glaucum*) ADR300 and ADR 7010 cultivars, rattlebox (*Crotalaria ochroleuca*), buckwheat (*Fagopyrum tataricum*), crambe (*Crambe abyssinica*) and brachiaria (*Urochloa ruziziensis*)] and the second one was five biomass levels (equivalent amount of straw) (2 t ha^{-1}, 4 t ha^{-1}, 8 t ha^{-1}, 12 t ha^{-1} and 16 t ha^{-1}, which corresponded to 0 g $plot^{-1}$, 19.3 g $plot^{-1}$, 38.5 g $plot^{-1}$, 76.9 g $plot^{-1}$, 115.5 g $plot^{-1}$ and 154.0 g $plot^{-1}$, respectively) on the soil, in addition to a control treatment without the use of cover crops.

Each experimental unit consisted of pots with 8 dm^3 (volume) and 35 cm (diameter). Vessels were filled with substrate samples taken from the layer of 40-60 cm of a dystrophic Latosol. This depth was chosen in order to avoid the upper soil layers, which contain the largest amount of weed seeds. Dolomitic lime was added to the soil to reach the base saturation of 50 %, and NPK fertilization (10:20:20) was performed at a dose of 0.4 g dm^{-3} of soil, corresponding to 800 kg ha^{-1}. *C. echinatus* was randomly sown with 30 seeds per pot. Seeds were covered with a soil layer of approximately 1.0 cm deep. The fresh matter of cover crops was collected and fractionated when the experiment was installed, avoiding the possible loss of allelochemicals, and put over the soil surface at different amounts of straw corresponding to 0 t ha^{-1}, 2 t ha^{-1}, 4 t ha^{-1}, 8 t ha^{-1}, 12 t ha^{-1} and 16 t ha^{-1} of dry biomass.

To obtain the cover crops biomass, the seeds were sown manually in a sandbox with 5 m², where plants developed, and their shoots were collected at the full flowering stage. Plant residues were grouped into sections of 2-3 cm, weighed and fixed by dry basis reference (dried in oven at 140 ºF, for 72 hours and/or until constant weight). Fresh biomasses were adjusted on the basis of the desired dry biomass per hectare, being subsequently homogenized and kept on the soil surface according to the treatments. Irrigation was performed on a daily basis.

The variables evaluated for the *C. echinatus* were: total number of emerged plants, germination speed index, leaf area, shoot dry biomass, root volume and root dry biomass. The germination speed index was calculated using the equation described by Maguire (1962):

$$GSI=\left[\frac{N_1}{1}+\frac{N_2\text{-}N_1}{2}+\frac{N_3\text{-}N_2}{3}+\ldots+\frac{N_n\text{-}N_n}{n}\right]$$

where N_1, N_2, N_3 ... N_n correspond to the number of seedlings identified in the first, second, third, ... and N^{th} days after sowing (DAS).

At 52 DAS, when the majority of the sandspur grass reached the pre-flowering stage, leaves were separated from shoots for measuring the leaf area, which was determined with a LI-3100 (LI-COR, Inc. Lincoln, NE, USA) equipment and expressed in cm^2 $plot^{-1}$. Roots were washed and separated from shoots (Basso 1999), in order to measure the root volume, expressed in cm^3 $plot^{-1}$. Both shoots and roots were dried at 140 ºF, until constant weight, to obtain their dry biomasses.

Statistical analyses were performed with Anova ($p \leq 0.01$) and the comparison of means for the qualitative factor (cover crops) was conducted using the Tukey test ($p \leq 0.01$) and Sisvar software, version 4.2 (Ferreira 2011). A regression analysis, using the Sigma Plot version 10.1 software, was performed for the quantitative factor (equivalent amount of straw).

RESULTS AND DISCUSSION

The total number of emerged plants, germination speed index, leaf area, root dry biomass, shoot dry biomass and root volume showed significant interactions ($p > 0.01$) between cover crops and straw levels (Table 1).

All cover crops showed potential to reduce the total number of emerged plants (Table 2 and Figure 1). Similar results were observed by Pacheco et al. (2013) with a significant control of *Bidens pilosa*, using 4.0 t ha^{-1} of biomass from *U. ruziziensis* and *Fagopyrum tataricum*. These results suggest that the physical effects of straw reduce the solar incidence on the soil surface, modifying the quality and reducing the amount of light, as well as inhibiting seeds germination. Monqueiro et al. (2009) also reported that the physical effect of straw interferes on the germination and seedling survival rate of some weed species.

U. ruzizienis was more efficient to control *C. echinatus*, in relation to other cover crops, and promoted significant reduction of *C. echinatus* emergence, starting at 4 t ha^{-1} of straw (Table 2 and Figure 1).

Table 1. Analysis of variance (F values) for the total number of emerged plants (TNEP), germination speed index (GSI), leaf area (LA), root dry biomass (RDB), shoot dry biomass (SDB) and root volume (RV) of *Cenchrus echinatus* using different levels of cover crops biomass (straw) on the soil surface (Bom Jesus, Piauí State, Brazil, 2013).

Source of variation	TNEP	GSI	LA	RDB	SDB	RV
Cover crop (CC)	9.77**	9.37**	17.47**	15.72**	8.16**	22.34**
Straw level (SL)	33.13**	42.42**	97.37**	27.70**	19.47**	62.34**
CC x SL	3.66**	4.05**	8.037**	7.84**	5.35**	15.67**
CV (%)	23.79	28.53	16.65	28.18	26.92	21.04

** Significant at 1 %.

Table 2. Total number of emerged plants and germination speed index as a function of cover crops and straw amounts on the soil surface (Bom Jesus, Piauí State, Brazil, 2013).

Treatments	Equivalent amounts of straw (t ha^{-1})					
Cover crop	0	2	4	8	12	16
	Total number of emerged plants per pot					
Penissetum glaucum cv ADR 7010	13.66 A[1]	10.66 A	9.33 A	8.33 B	7.00 B	5.66 B
Crotalaria ochroleuca	13.66 A	9.33 A	9.33 A	9.26 B	7.33 B	5.66 B
Urochloa ruziziensis	13.66 A	9.00 A	5.33 A	4.33 A	3.00 A	1.66 A
Fagopyrum tataricum	13.66 A	9.33 A	9.30 B	9.30 B	8.66 B	7.00 B
Penissetum glaucum cv *ADR 300*	13.66 A	10.00 A	9.33 B	8.33 B	7.00 B	5.00 B
Crambe abyssinica	13.66 A	9.33 A	9.00 B	8.33 B	7.66 B	6.66 B
	Germination speed index					
Penissetum glaucum cv ADR 7010	3.02 A	2.20 A	1.94 B	1.43 A	1.29 A	1.05 AB
Crotalaria ochroleuca	3.02 A	1.80 A	1.55 AB	1.44 A	0.82 A	0.61 A
Urochloa ruziziensis	3.02 A	1.92 A	1.33 A	1.23 A	1.21 A	0.05 A
Fagopyrum tataricum	3.02 A	2.79 A	2.52 B	2.41 B	2.07 B	1.52 B
Penissetum glaucum cv *ADR 300*	3.02 A	2.92 A	2.39 B	1.52 A	1.27 A	1.01 AB
Crambe abyssinica	3.02 A	2.36 A	1.71 AB	1.62 A	1.22 A	1.02 AB

[1] Means followed by the same letter in the column do not differ significantly by the Tukey test at 1 %.

Gimenes et al. (2011) analyzed the effect of *U. decumbens* on weed control and found a decrease from 30 to 2 *C. echinatus* plants m^{-2}, when compared to the control treatment. The *Urochloa* species has high amounts of phenol group substances and flavonoids (Waborne & Williams 2000, Lisboa 2009), which can act as suppressors of *C. echinatus* germination.

Germination of *C. echinatus* may be influenced by the release of allelochemical substances during biomass decomposition (Alvarenga et al. 2001, Salton 2004, Vidal & Trezzi 2004). Additionally, the biomass on soil surface provides great physical control of weeds and reduces the light necessary to stimulate the *C. echinatus* germination (Theisen et al. 2000, Severino & Christofoletti 2001, Sodré Filho et al. 2008).

Leaf area and shoot dry biomass of *C. echinatus* L. were reduced in 72 % and 90 %, respectively, when the seedlings were below 8 t ha^{-1} of *U. ruziziensis* biomass (Table 3 and Figure 2).

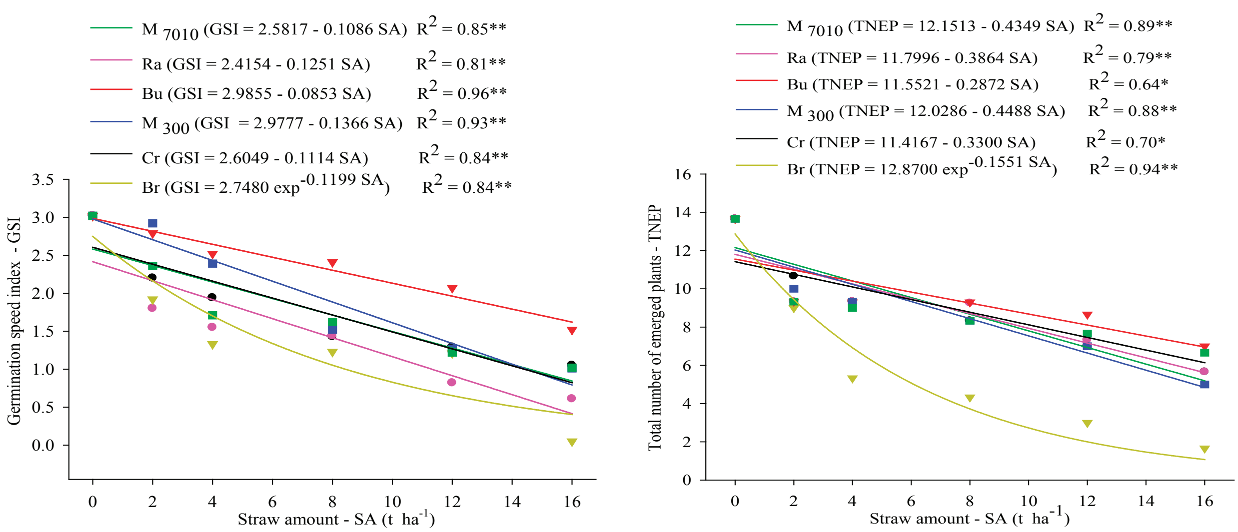

Figure 1. Regression analyses of germination speed index and total number of emerged plants of *Cenchrus echinatus* L. as a function of cover crop and straw amount on the soil surface (Bom Jesus, Piauí State, Brazil, 2013). Cover crops: M_{7010} - millet ADR 7010; Ra - rattlebox; Bu - buckwheat; M_{300} - millet ADR 300; Cr - crambe; Br - brachiaria. *, **: significant at 5 % and 1 %, respectively.

Table 3. Shoot dry biomass and leaf area of *Cenchrus echinatus* L. plants as a function of cover crop and amount of straw on the soil surface (Bom Jesus, Piauí State, Brazil, 2013).

Treatments	Equivalent amounts of straw (t ha^{-1})					
Cover crop	0	2	4	8	12	16
	Shoot dry biomass (g pot^{-1})					
Penissetum glaucum cv ADR 7010	6.61 A[1]	6.10 B	4.45 AB	3.45 B	3.10 B	3.00 B
Crotalaria ochroleuca	6.61 A	5.00 AB	4.00 AB	3.80 B	3.33 B	3.01 B
Urochloa ruziziensis	6.61 A	4.00 A	3.00 A	1.80 A	1.10 A	0.90 A
Fagopyrum tataricum	6.61 A	6.10 B	5.10 B	5.10 C	5.00 B	3.90 B
Penissetum glaucum cv *ADR 300*	6.61 A	6.02 B	5.00 B	4.80 C	3.32 B	2.95 B
Crambe abyssinica	6.61 A	5.00 AB	4.97 B	4.88 C	4.00 B	3.00 B
	Leaf area (cm^2 pot^{-1})					
Penissetum glaucum cv ADR 7010	1,101.1 A	703.8 B	538.8 B	384.6 B	351.3 B	345.7 C
Crotalaria ochroleuca	1,101.1 A	556.6 A	556.5 B	450.5 B	411.4 B	393.9 C
Urochloa ruziziensis	1,101.1 A	643.5 AB	228.5 A	99.2 A	74.7 A	33.1 A
Fagopyrum tataricum	1,101.1 A	875.7 B	752.9 C	763.8 C	605.6 C	386.5 C
Penissetum glaucum cv *ADR 300*	1,101.1 A	823.0 B	643.7 C	427.5 B	282.0 AB	137.5 B
Crambe abyssinica	1,101.1 A	746.6 B	738.3 C	663.5 C	553.3 C	411.6 C

[1] Means followed by the same letter in the column do not differ significantly by the Tukey test at 1 %.

Gimenes et al. (2011) also demonstrated that 10 t ha^{-1} of *U. decumbens* biomass at 60 days after germination were sufficient to reduce more than 80 % of the leaf area of *Digitaria horizontalis* and *C. echinatus*. The symptoms of allelopathic effects from cover crops are yellowing or chlorosis of leaves, which causes their fall, and a decrease in shoot dry biomass (Almeida 1985).

U. ruziziensis also promoted the greatest reduction in root growth of *C. echinatus* (Table 4 and Figure 3). The reduction of the *C. echinatus* root system should result in a reduction of the competitive ability of the weed to uptake water and nutrients, especially under water stress conditions.

C. ochroleuca exponentially reduced the root volume of 60 % of weeds with up to 2 t ha^{-1} (Table 4 and Figure 3). This effect may be due to the different allelopathic responses that might be attributed to phenols and flavonoids, such as inhibition and activation of enzymes (Simões et al. 2004), and the

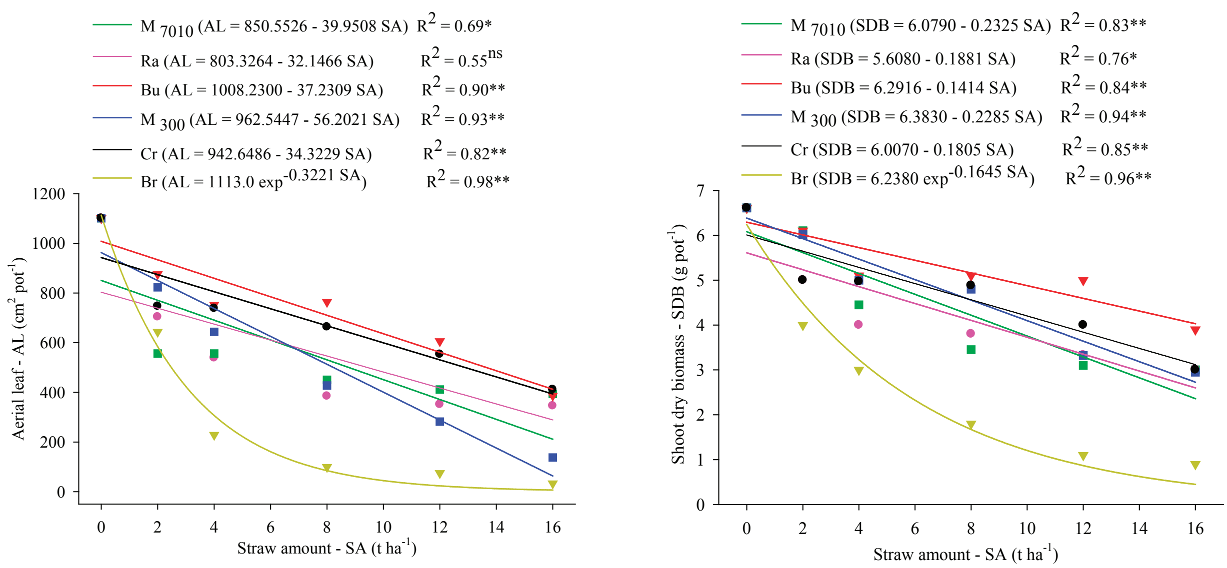

Figure 2. Regression analyses of shoot dry biomass and leaf area of *Cenchrus echinatus* L. plants as a function of cover crop and straw amount on the soil surface (Bom Jesus, Piauí State, Brazil, 2013). Cover crops: M_{7010} - millet ADR 7010; Ra - rattlebox; Bu - buckwheat; M_{300} - millet ADR 300; Cr - crambe; Br - brachiaria. *, **: significant at 5 % and 1 %, respectively.

Table 4. Root volume and root dry weight of *Cenchrus echinatus* L., at 50 days after sowing, as a function of cover crops and amount of straw on the soil surface (Bom Jesus, Piauí State, Brazil, 2013).

Treatments	Equivalent amounts of straw (t ha^{-1})					
Cover crop	0	2	4	8	12	16
			Root volume (cm^3 pot^{-1})			
Penissetum glaucum cv ADR 7010	53.00 A[1]	28.66 A	26.33 A	24.00 B	23.66 B	18.00 B
Crotalaria ochroleuca	53.00 A	26.00 A	22.66 A	21.66 B	20.66 B	18.23 B
Urochloa ruziziensis	53.00 A	30.00 A	26.66 A	11.33 A	2.33 A	2.00 A
Fagopyrum tataricum	53.00 A	43.33 B	39.33 B	37.33 C	33.66 B	27.00 C
Penissetum glaucum cv *ADR 300*	53.00 A	41.33 B	40.00 B	36.66 C	32.00 B	13.33 B
Crambe abyssinica	53.00 A	45.33 B	43.33 B	36.66 C	29.33 B	26.33 C
			Root dry biomass (g pot^{-1})			
Penissetum glaucum cv ADR 7010	4.40 A	3.10 AB	2.70 A	2.50 B	2.10 B	2.00 B
Crotalaria ochroleuca	4.40 A	4.00 B	2.60 A	2.50 B	2.20 B	2.00 B
Urochloa ruziziensis	4.40 A	2.10 A	2.00 A	1.00 A	1.00 A	0.80 A
Fagopyrum tataricum	4.40 A	3.20 AB	3.00 A	3.00 B	2.80 B	2.70 B
Penissetum glaucum cv *ADR 300*	4.40 A	4.30 B	2.90 A	2.90 B	2.20 B	1.40 B
Crambe abyssinica	4.40 A	4.40 B	3.00 A	2.80 B	2.50 B	2.20 B

[1] Means followed by the same letter in the column do not differ significantly by the Tukey test at 1 %.

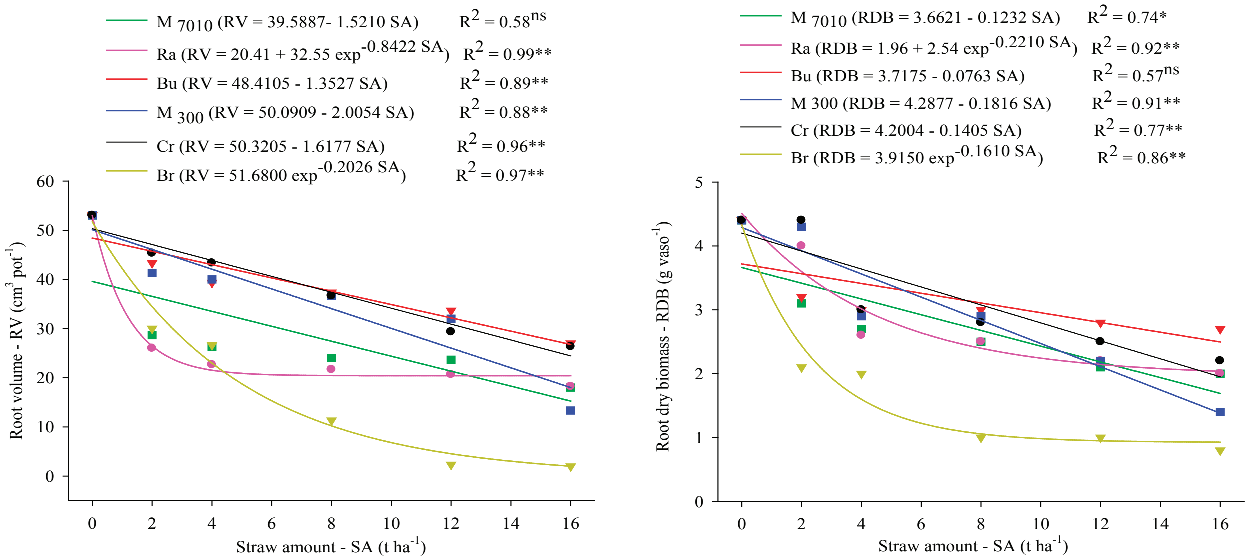

Figure 3. Regression analysis of root volume and root dry biomass of *Cenchrus echinatus* L. as a function of cover crop and amount of straw on the soil surface (Bom Jesus, Piauí State, Brazil, 2013). Cover crops: M_{7010} - millet ADR 7010; Ra - rattlebox; Bu - buckwheat; M_{300} - millet ADR 300; Cr - crambe; Br - brachiaria. ^{ns}, * and **: not significant and significant at 5 % and 1 %, respectively.

attraction or repulsion of microorganisms (Andrade et al. 2007). Furthermore, it is known in the literature that growth inhibition may result in reduction of root elongation (Baziramakenga et al. 1994, Ferrarese et al. 2000).

The amount of 2 t ha^{-1} of biomass residues of *C. ochroleuca* significantly reduced the weed root volume. This result may be explained by the oxidizing of substances released during the mineralization process of plant residues (Cunha & Roque 2005). The concentration of phenols and flavonoids in the soil were reduced over 80 % in only 14 days, because of their fast oxidation (Lisboa 2009).

Our results indicate that the cover crops *U. ruziziensis* and *C. ochroleuca* are effective in controlling the development of *C. echinatus*. Thus, these species can be used as tools in the integrated management of this weed, reducing the use of herbicides and the production cost.

CONCLUSIONS

1. The increase in the amount of cover straws on the soil surface improves the control of *C. echinatus*.
2. All cover crops tested reduce the emergence and development of *Cenchrus echinatus*, when a minimum of 4 t ha^{-1} of biomass is on the soil surface.
3. *Uroclhoa ruziziensis* is the most efficient cover crop for controlling the germination speed index, emergence, shoot and root dry biomass, leaf area and root volume of *C. echinatus*.
4. An equivalent amount of straw of 2 t ha^{-1} of *Crotalaria ochroleuca* is sufficient to significantly reduce the root volume of *C. echinatus*.

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