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Suppression effect of *Crotalaria ochroleuca* cover crop on *Amaranthus deflexus* emergence and development

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Abstract

The weed infestation suppression by chemicals released by plants can occur due to crop residues left on the soil surface or through the incorporated straw in the soil. The aim of this study was to evaluate the suppression of *Amaranthus deflexus* as a result of cover crops and residue amounts of *Crotalaria ochroleuca*. The experiment was conducted in a greenhouse from May to August, 2014. The experimental design was a randomized block with four repetitions. The treatments were arranged in a factorial scheme (3 x 5) + 1, with the following factors : (A)-management of the cover crops (incorporated, incorporated + surface and soil surface) ; (B)-straw levels (3, 6, 9, 12 and 15 t ha $^{-1}$) and a control treatment without the use of cover crop (control - 0 t ha^{-1}). The evaluated variables were: total number of emerged plants, emergence speed index, dry mass, leaf area, root dry mass and root volume. The management of different straw amounts was efficient, mainly when the incorporate+surface and surface in suppressing of *A. deflexus* forms were used.

Keywords: Allelopathy, *Crotalaria ochroleuca*, crop management.
Abbreviations: TNEP_Total number of emerged plants; SEI_ Speed emergency index; LA_Leaf area; SDM_Shoot dry mass; RV_Root volume; RDM_Root dry mass.

Introduction

The development of *Amaranthus* spp. is becoming a problem faced by growers in agricultural areas of the Brazilian Cerrado due to the difficult control, especially in areas with cotton cultivation. Furthermore, plants are characterized by being aggressive and strong competitors with cotton plants, with depreciation potential over the cotton fiber (Jha et al., 2008; Chauhan and Johnson, 2009). The *Amaranthus* genus comprises about 60 species, which are commonly found in crops. In regions of the United States, *Amaranthus* spp. is considered the third largest weed problem in relation to control and interference in crops, and the second bigger problem for the cotton crop (Steckel, 2007; Wise et al., 2009).

Due to the extended period of germination and fast growth, the control of the *Amaranthus* genus in post-emergence can be hindered, besides the herbicidal applications that are highly dependent on climate conditions for obtaining a product efficiency (Falk et al., 2006; Zanatta et al., 2008). Still connected to that genus is the fact of the existence of fast selection and spread of resistant biotypes to several groups of herbicides when applied in post-emergence (Patzoldt and tranel, 2007; Duff et al., 2009). With the use of winter cover and/or between the harvest period, some particular species may show variability in response to the control practice, even when there are changes in the number of individuals and composition of weed species (Voll et al., 2005). Boosted by the ability of some plants to show potential in suppressing the growth of other species, it is possible to maximize productivity, reduce the costs of weed control and minimize the negative risks to environment (Velykis and Satkus, 2006). The no-tillage system stands out as a viable alternative to control these weeds. According to Pacheco et al. (2009), the production of biomass and soil cover are factors that can help in the control through physical and chemical processes (allelopathy). According to Correia et al. (2006), the residue amount on the soil can affect weeds composition and density. The physical effect of mulch helps the soil shading, inhibiting seed germination and infestation of some weeds, enabling the main crop to start its development with lower initial competition (Queiros et al., 2010). The allelopathic effects from the decomposition of biomass or exuding of roots have an inhibitory effect on seed germination or interfere on the development process. Therefore, growth is delayed or stalled, with plant death in some cases (Alvarenga et al., 2001).

One of the assumptions for success in biomass production and fast establishment capacity is choosing the species of cover crops that are adapted to the local growing conditions, which will assist the weed control (Alvarenga et al., 2001; Pacheco et al., 2013a). Also, another important aspect is the performance of cover crops in drought conditions (Petter et al., 2013). The *Crotalaria ochroleuca* is a common species used in 'cerrado' region as a cover crops and some studies stated the efficiency of the species on *Bidens pilosa* (Pacheco et al., 2013) and *Cenchrus echinatus* L. (Silva et al., 2015) control. However, no researches about the effect of this species in the *A. deflexus* management for this region was found on literature. Thus, the aim of this study was to evaluate the *A. deflexus* supression using *C. ochroleuca* as cover crop with different residue levels.

Results and Discussion

D. horizontalis seedling emergence

For the variable number of emerged plants (NEP) of *A. deflexus*, no significant interaction was observed ($P > 0.05$) among the forms of management and residue levels, while individual effect among factors of this variable was observed (Table 1). For the management form, the use of the residue in the surface showed a high potential, since it reduced the seedling emergence. These results reinforce the importance of the presence of residue on the soil surface at the time of sowing, in order to assist the weed control (Pacheco et al., 2013b). Erasmus et al. (2004) observed benefits with the use of cover crops in weed control up to 60 days after desiccation.

The presence of green or mulch plants that remains on the soil tends to provide a significant reduction in the establishment of weeds due to the decrease of the temperature range (Severino, and Christoffoleti, 2001), creating a physical barrier (Gomes and Christoffoleti 2008), to weeds emergence. Monqueiro et al. (2009) related that the physical effect of the residue can provide a significant reduction on germination and on the survival rate of weed seedlings.

Shoot development of D. horizontalis

A significant interaction between the residue levels and the form of application was observed for the variables leaf area (LA) and shoot dry mass (SDM) of *A. deflexus* ($P < 0.05$), according to Table 1. All studied management forms presented potential to reduce the *A. deflexus* leaf area (LA), mainly when the residue was applied on the surface, with statistically different results when compared to others (Table 1). For SDM, the lower mean for this variable was observed when the management incorporated + surface was used, with a reduction of 40.04% (Table 1).

According to Almeida (1985) the symptoms of the allelopathic effects with the use of cover crops can promote chlorosis, causing leaf fall and a reduction on SDM. In studies by Moraes et al. (2010), promising results were found on LA and SDM of *Bidens pilosa* with the use of 4 t ha^{-1} of Azevém (*Lolium multiflorium*) phytomass maintained on soil surface, showing a significant reduction on these variables.

The management forms tested presented decreasing exponential behavior for the variables LA and SDM of *A. deflexus*, except when the residue were incorporated for the variable LA (Fig 1), with a higher significant reduction for these variables for the initial amounts of residue. Thus, the higher reductions for the variables LA and SDM were with 3 t ha^{-1} of residue applied on surface, with 90.5% of reduction, when compared to control (0 t ha^{-1} of residue) (Table 2 and Fig 1). For the variable SDM, the higher reductions were also observed with 3 t ha^{-1} of residue incorporated + surface and surface with reductions of 59.06% and 71.46%, when compared to control (0 t ha^{-1} of residue) (Table 2 and Fig 1).
Pacheco et al. (2013b) proposed that the delay on seedlings emergence occurs because of the residue on soil surface is efficient to avoid or delay the presence of weed plants on the area, since the LA and SDM reductions make the weeds less competitive with the crops.

D. horizontalis root development

For the variables root dry mass (RDM) and root volume (RV) of *A. deflexus*, a significant interaction was observed ($P<0.01$) between the management forms and residue amount (Table 1). All the forms of management were effective in reducing the RDM and RV of *A. deflexus*, especially the incorporated+surface and surface management, providing a greater root system reduction of the studied weed plant (Table 1).

Silva et al. (2015), studying cover crops to suppress *Cenchrus echinatus L.* development, observed positive effects of *C. ochroleuca* residue on RDM and RV of *Cenchrus echinatus L*, with a reduction of 59.13% and 43.18%, respectively, for the residue level of 8 t ha^{-1}, when compared to the control (0 t ha^{-1} of residue).

For the variables RDM and RV of *A. deflexus*, the management forms presented decreasing exponential behavior, except for the incorporated management for RDM, which presented a linear behavior (Fig 2). For RDM, the initial residue amounts, the surface + incorporated and surface management promoted the higher reductions, especially at the level of 6 t ha^{-1}, that promoted a reduction of 57.70 and 38.90, respectively, compared to the control (0 t ha^{-1} of residue) (Table 2 and Fig 1). For the variable RV, the treatment incorporated + surface biomass promoted the higher reduction on root growth of *A. deflexus,* mainly using 3 t ha^{-1} of residue, with a reduction of 69.44%, when compared to the control (Table 2 and Fig 2). However, after the application of 6 t ha^{-1} of residue, the management on surface promoted a higher reduction on *A. deflexus* root volume (63.88%), compared to the control (0 t ha^{-1} of residue) (Table 2 and Fig 2). In a study of Pacheco et al. (2013b), similar results were found with the use of 8 t ha^{-1}.
An explanation for this behavior is due to the physical effects provided by the soil cover and the allelopathic effects provided by the release of natural substances (Vidal and Trezzi, 2004) during the biomass decomposition, that are able to reduce the seedlings germination and development. Thus, the residue affects the development of shoot and the root development of weed plants. Moreover, the literature reports that the inhibition of root growth can lead to a reduction in the shoot area (Dexter, 2004).

Materials and Methods

Location and characterization of the experimental area

The experiment was carried out in a greenhouse during the period of May to August, 2014, at the Federal University of Piauí, Professor Cinobelina Elvas Campus (UFPI / CPCE), located in Bom Jesus (9º 16' 78" S latitude, 44º 44' 25" W longitude and altitude of 300 meters) in the state of Piauí, Brazil.

Establishment and management of the experiment

It was adopted a randomized complete block design with four replications in a (3 x5)+1 factorial scheme, with the factor A composed of forms of management (incorporated, incorporated + surface and surface) and factor B consisting of

Table 1. Variance analysis (F values) for *A. deflexus* number of emerged plants (NEP), leaf area (LA), shoot dry mass (SDM), root dry mass (RDM) and root volume (RV).

Source of variation	NEP	LA	SDM	RDM	RV
Management (M)	288.46**	772351.81**	33.23**	5.14**	135.47**
Incorporated (I)	9.00 b	463.12 a	4.92 a	1.12 a	7.37 a
Surface (S)	5.00 c	134.44 c	2.10 b	0.59 b	3.02 b
I + S	12.00 a	261.18 b	2.95 b	0.62 b	3.53 b
Residue amount (RA)	98.28**	162289.94**	34.08**	0.38**	57.54**
M x RA	12.55^{ns}	36128.21**	11.20**	0.72**	7.79**
CV	21.56	29.93	28.28	20.24	25.40

**significant at 1%; at 5%; ^{ns}not significant. CV – coefficient of variation.

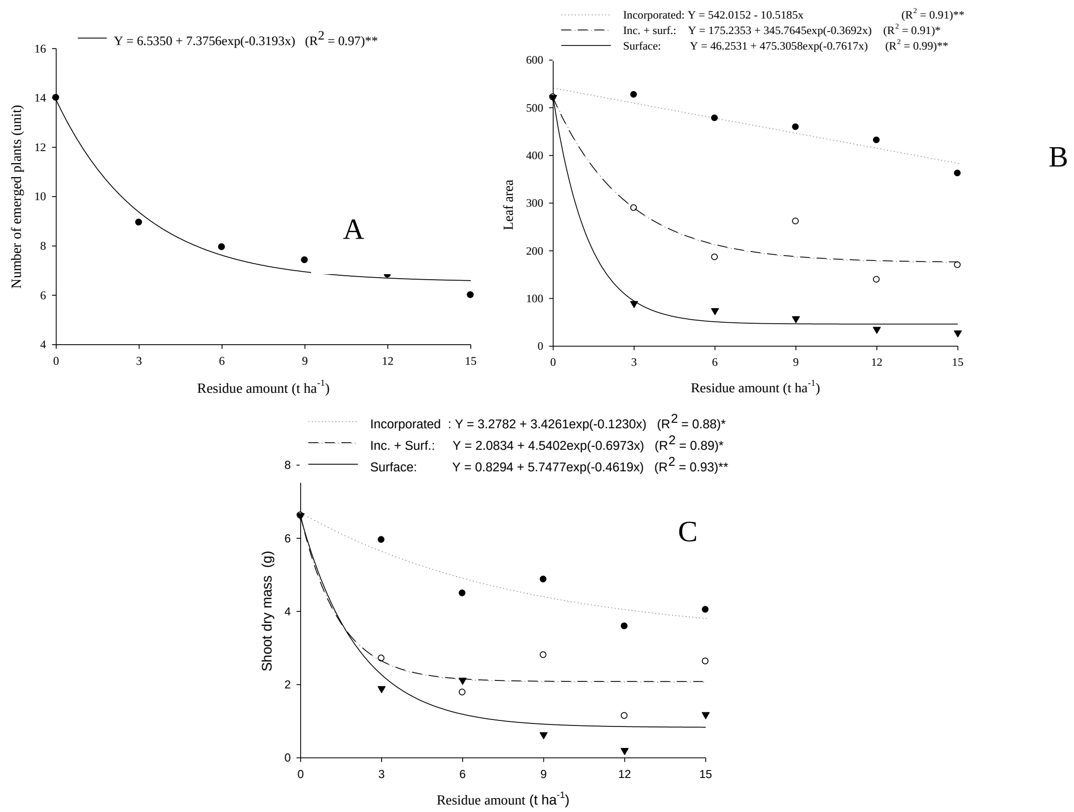

Fig 1. Number of emerged plants (A), leaf area (B), and shoot dry mass (C) of *Amaranthus deflexus* according to the management and residue amount of *Crotalaria ochroleuca.* ** and * significant at 1% and 5%, respectively.

Table 2. Significant interactions for leaf area (LA), shoot dry mass (SDM), root dry mass (RDM) and root volume (RV) of *Amaranthus deflexus*.

Management	Residue amount					
	0	3	6	9	12	15
	Leaf area					
Incorporated (I)	521.82 a	526.95 a	477.66 a	458.94 a	431.36 a	485.89 a
Surface (S)	521.82 a	49.58 c	74.60 b	57.58 b	35.31 b	27.79 b
I + S	521.82 a	289.37 b	186.08 b	296.82 a	138.93 b	169.54 b
	Shoot dry mass (g)					
Incorporated (I)	6.62 a	5.95 a	4.49 ab	5.58 a	3.59 a	4.04 a
Surface (S)	6.62 a	1.89 b	6.12 a	0.63 b	0.20 b	1.18 a
I + S	6.62 a	2.71 b	1.78 b	5.35 a	1.14 ab	2.63 a
	Root dry mass (g)					
Incorporated (I)	1.16 a	1.31 a	1.09 a	1.13 a	2.44 a	1.42 a
Surface (S)	1.16 a	0.61 b	0.71 ab	0.50 b	0.37 b	0.24 b
I + S	1.16 a	0.77 b	0.49 b	0.75 ab	0.32 b	0.43 b
	Root volume (cm^3)					
Incorporated (I)	9.00 a	7.12 a	6.94 a	7.22 a	6.67 a	7.26 a
Surface (S)	9.00 a	3.48 b	3.25 b	1.00 c	0.49 b	0.93 b
I + S	9.00 a	2.75 b	2.06 b	3.30 b	1.96 b	2.11 b

Means followed by the same letter in column are not different according to Tukey´s test at 5% of probability.

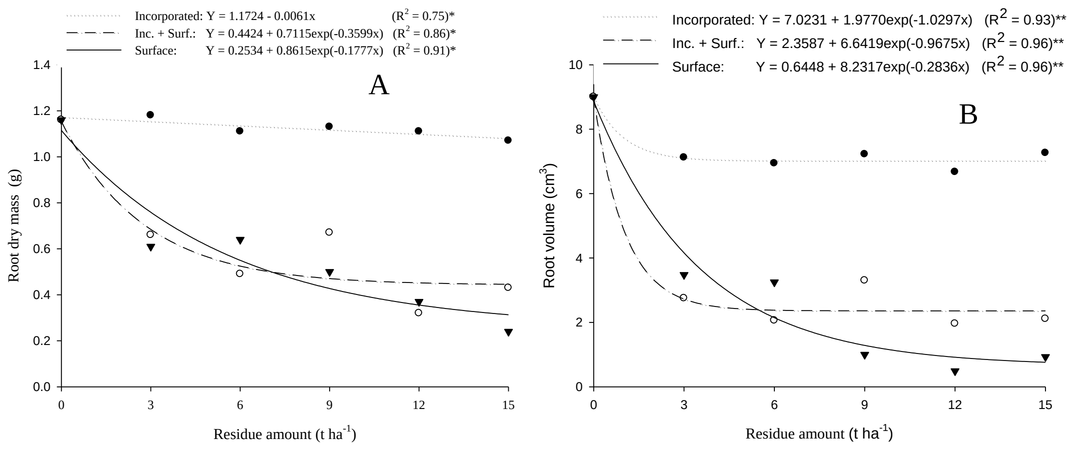

Fig 2. Root dry mass (A), and root volume (B) of *Amaranthus deflexus* according to the management and *Crotalaria ochroleuca* residue amount. ** and * significant at 1% and 5%, respectively.

five levels of *Crotalaria ochroleuca* residue (3, 6, 9, 12 and 15 t ha^{-1}), and another treatment without the use of cover plants (control = 0 t ha^{-1}), totaling 64 experimental units.

Each experimental unit consisted of pots with 8 dm^3 capacity of soil and 35 cm in diameter, that were randomly sown with 30 seeds of *Amaranthus deflexus* weed per pot, covered with a layer of approximately 1.0 cm of soil. The substrate used in the pots was collected from 40-60 cm soil layer in a Dystrophic Yellow Latosol. This depth was adopted in order to avoid a larger database of existing weed seeds in the upper layers.

The fresh plant cover was applied in three management forms. In the first one, it was only incorporated into the soil, in the second, a part has been incorporated and the other part added to the soil surface and in the third, all the fresh plant cover was added over the soil surface in amounts corresponding to the treatments (3, 6, 9, 12 and 15 t ha^{-1} of dry weight). The plant material was collected and fractionated in the installation day of the experiment to avoid a possible allelochemicals loss.

To obtain the biomass, the seeds of cover crops were sown by hand and grown in 5 m² beds. The shoot parts of these plants were collected when they were in the reproductive stage (beginning of the flowering stage ± 60 days after emergence, considering the crop cycle). The plant residues were segmented into sections of 2 to 3 cm approximately, weighed and fixed by a dry basis reference. Then, the plant samples remained in an oven at 65°C for 72 hours and/ or until constant weight. The fresh material was adjusted as the desired dry matter per hectare, according to the treatments. The crop received water according to its daily needs.

Studied variables

The variables were: number of emerged plants (NEP), leaf area (LA), shoot dry mass (SDM), root volume (RV) and root dry mass (RDM). The NEP was determined by counting the total number of plants in each experimental unit at the end of the experiment. The leaf area (LA) was obtained when most of the weeds achieved the pre-flowering stage with the use of LI-3100 area meter (LI-COR, Inc. Lincoln, NE, USA) expressed in cm^2 pot^{-1}, when the leaf was separated from the steam. Besides that, the roots were separated from the shoot parts, washed with water and removed from the soil to root volume measurement, using the graduated cylinder method (Basso, 1999) expressed in cm^3 pot^{-1}. For dry mass data, the shoot and root were submitted to oven at 65ºC until a constant weight.

Statistical analysis

Data were submitted to variance analysis (F test, p<0,05) and when significant, the qualitative data were submitted to Tukey´s test at 5% of probability with Assistat 7.7 software. The quantitative treatments were adjusted with regression equations, with the aid of Sigma Plot software 10.1.

Conclusions

All the tested management forms have the potential of reducing *Amaranthus deflexus* infestation. The surface management is the most effective way of controlling *Amaranthus deflexus.* An equivalent amount of 3 t ha^{-1} of *Crotalaria ochroleuca* dry mass is enough to reduce significantly the *Amaranthus deflexus* emergence and growth. Incorporate + surface and surface management showed a greater reduction in the root system parameters.

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