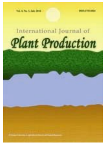

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Ideal desiccation periods of *Urochloa ruziziensis* for a no-till sunflower crop

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Abstract

Sowing crops following cover crops on forage may cause injuries and productivity reduction, due reasons as allelopathy or glyphosate residues. The objective of this study was to evaluate the influence of differing periods between cover crop (*Urochloa ruziziensis*) desiccation with glyphosate and sunflower (Aguará 4) sowing in a no-tillage system on crop development and productivity. Two assays were performed in two seasons, one in pots and the other in a field. Treatments in field assay consisted on 5 desiccation times of *U. ruziziensis* (with an application of glyphosate at 1.08 kg ae ha^{-1}) preceding the sowing of no-till sunflower (0, 3, 7, 10 and 30 days). At the pot assays, 6 times were studied: 0, 3, 7, 10, 15 and 20 days between cover crop desiccation and sunflower sowing. A control without cover crop was also included in this assay. Biometric evaluations were performed at the vegetative stage and at harvest. As the period between *U. ruziziensis* desiccation and sunflower sowing was shortened, achene production in sunflower was exponentially reduced. Glyphosate application at 3 or 0 days pre sowing diminished sunflower development and achene production by approximately 30% compared to desiccation periods greater than 7 days.

Keywords: Glyphosate; Allelopathy; Cover crop.

Introduction

In a no-till system, it is essential to use efficient sources of cover crops, such as species of the genus *Urochloa* (Syn. *Brachiaria*). *Urochloa* *ruziziensis* (R. Germain and C. M. Evrard) is considered, for many growers, to be the most convenient cover crop for a no-till system. This plant has prostrate growth and a low tussock, which facilitates no-till seeder performance. Furthermore, it is highly sensitive to glyphosate, resulting in quick death, which helps with desiccation operations and mechanized sowing. *U. ruziziensis* has a high C/N ratio, which ensures the presence of soil cover for an extended period of time (Souza et al., 1999).

Chemical control of no-till cover crops is performed with non-selective systemic herbicides such as glyphosate (Cerdeira and Duke, 2006). The effect of glyphosate may not be limited to target plants and can be metabolized to non-toxic compounds and/ or exuded to the soil.

Sunflower is a crop that fits in a no-till system, Anderson et al. (1996) had compared sunflower productivity in different cultivation systems and their results showed similar production levels between no-till and conventional till systems. Sowing this crop following cover crops, however, may cause injuries and productivity reduction. The cause of this effect may be the result of several factors: the action of allelopathic cover crops or, indirectly, by the desiccant herbicide effect. Allelochemicals and glyphosate and/or its byproducts, can be released by the cover crop's root exudation or leached during its biomass decomposition. Additionally, these compounds may be absorbed by the next crop planted (Chou and Patrick, 1976; Linder et al., 1964; Neumann et al., 2006; Perez and Nunez, 1991).

The goal of this research was to study the effects of five periods (0, 3, 7, 10 and 30 days) of *U. ruziziensis* desiccation with glyphosate in pre-sowing on sunflower productivity.

Materials and Methods

Field assay

The field assay was carried out in the agricultural year of 2009/2010, at an experimental area in Jaboticabal (latitude 21º 17' S, longitude 48º 18' W, altitude 590 m), São Paulo State, Brazil. The soil was a Clayey Red Latosol (Oxisol) and the field was established with *U. ruziziensis*.

The treatments were five periods (0, 3, 7, 10 and 30 days) of desiccation before sunflower sowing. The experimental design utilized was randomized blocks with four replications.

The cover crop was desiccated with glyphosate herbicide at a dosage of 1.08 kg ae ha^{-1}. The application was performed with a CO_2 pressurized backpack sprayer with 110 02 nozzles. The pressure was kept constant, at 2.0 bar and the sprayer was adjusted to spray a volume of 200 L ha^{-1}. Each plot had 5 rows, which were 10 m long, creating a total area of 45 m^2.

Sunflower hybrid used was Aguará 4, the sowing was done in 18 Dec 2009, with row spacing of 0.9 m, forming a population of 40,000 plants ha^{-1}.

Data of pluvial precipitation during the assay period is shown in Figure 1.

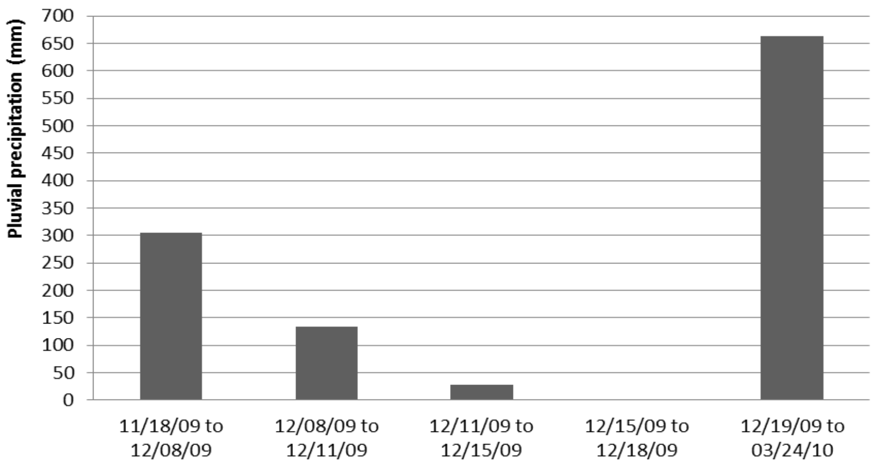

Figure 1. Pluvial precipitation (mm) during the five periods between cover crop desiccation and sunflower sowing. Source: Agricultural Station, Department of Exact Sciences of UNESP. Jaboticabal, São Paulo State, Brazil, 2010.

A complete NPK (nitrogen, phosphorus and potassium) fertilizer was spread at a rate of 300 kg ha^{-1} (4-14-8 formulation) during the sunflower sowing. Thirty days after sowing, topdressing was performed with 90 kg ha^{-1} of urea and 11 kg ha^{-1} of borax.

For sunflower caterpillar control (*Chlosyne lacinia saundersii* Doubleday and Hewitson), two pulverizations of the mixed insecticide thiamethoxam + lambda-cyhalothrin (28.2 mL + 21.2 mL ai ha^{-1}) were applied. For the prevention of powdery mildew (*Erysiphe cichoracearum* DC.) infestation, two fungicide applications of azoxystrobin + cyproconazole (40 mL + 16 mL a. i. ha^{-1}) were performed.

Dry matter of *U. ruziziensis* was determined by collecting samples from a 0.25 m² square cast steel frame, thrown four times randomly. The material in the square was cut at ground level, placed on paper bags and dried in a forced air oven at 60 ºC until constant dry weight was reached. The results of the dry matter measurements were approximately 6 t ha^{-1} during the desiccation periods prior to the sunflower sowing. There were no differences between cover crop biomass from the different periods (results not presented); therefore, all treatments had an equivalent amount of cover.

At 25 days after sowing (DAS), biometric evaluation of the cover crop was performed. Six sunflower plants per plot were collected. Height (cm), leaf area (cm², through LICOR, model LI 3000 A), number of leaves and dry matter of the stem and leaves (g) were evaluated.

When sunflower capitula formed fruits (achenes), they were covered with impermeable paper bags to prevent bird attacks. At 95 DAS, all plants were collected from the 8 central meters and stem diameter (mm, at 2 cm from the soil), capitula diameter (cm), height (cm) and achene production (kg ha^{-1}) were measured. The harvest was performed manually and productivity adjusted to 11% of grain moisture.

Data obtained was analyzed statistically with an F test analysis of variance and a Scott-Knott test for comparing the means was performed, both with 5% probability. Results of achene production from this assay were also utilized for regression analysis (by Microcal Origin 6.1 software).

Pot assay

The pot assay was carried out in a greenhouse, in the agricultural year of 20011/12, at an experimental area in Jaboticabal, São Paulo State, Brazil. Plots consisted on pots with a volume of 20 L and were filled with soil collected from topsoil with the same features as the soil used in the field assay.

The assay consisted of seven treatments, including six time treatments (0, 3, 7, 10, 15 and 20 days) between desiccation of the cover crop and sunflower sowing and a control with no cover crop and no glyphosate application. The experimental design was completely randomized.

The cover crop used was *U. ruziziensis,* which was germinated in polyethylene trays. After germination, the seedlings were transplanted into pots with a density of 80 plants m^{-2}. Sowing and transplantation of the cover crop followed the chronological order for each period of desiccation. This process ensured that the forages were the same ages and masses when the desiccation was performed. For each cover treatment, an additional replicate was used to collect the cover on the day of sunflower sowing. The material collected was dried in order to obtain the dry matter per area. The dry matter of *U. ruziziensis* grown in the pots did not differ between the treatments, average being 6.8 t ha^{-1}.

The cover crop desiccation was performed with glyphosate applications at a dosage of 1.08 kg ae ha^{-1}. The applications were performed with a CO_2 pressurized backpack sprayer with the same settings that were used in the field assay. The pots were moved to an application room for the desiccation and then they were placed back in the greenhouse. The irrigation was controlled after the application of glyphosate, with 14 mm of water administred daily.

The sunflower hybrid sown was the same as the one sown in the field assay. The sunflower sowing was on 14 Sep 2011. Ten days after sowing, plants were thinned to four sunflower plants per pot. The same cultural treatments used in the field assay, including plant nutrition and crop pest management, were used.

The biometric features of two sunflower plants per pot were evaluated at 35 DAS. They were: height (cm), number of leaves, leaf area (cm²), stem diameter (mm) and dry mass of stems and leaves (g). At harvest stage (110 DAS) height (cm), diameter of stems (mm) and capitula (cm), dry mass of stems (g) and leaves (g) and achene production (kg ha^{-1}) of two plants per pot were evaluated.

An F test was performed on the collected data and averages were compared with a Scott-Knott test with 5% probability. The results of achene production from this assay were also analyzed using regression analysis (by Microcal Origin 6.1 software).

Results

Field assay

The desiccation of *U. ruziziensis* preceding sunflower sowing for the periods of 0 and 3 days reduced all traits evaluated at 25 DAS when compared to 10 and 30 days (Table 1). The 0 day sowing produced the smallest plants of all the treatments. The sunflowers from the periods of 30 and 10 days were taller than the plants from the treatments of 7 and 3 days. For all other traits, the plants from the periods of 30, 10 and 7 days were more vigorous than the ones from the shorter periods of desiccation.

Table 1. Height, leaf area, number of leaves and dry mass of leaves and stem per sunflower plant; evaluated 25 days after sowing under different periods after cover crop desiccation.

Periods	Height (cm)	Leaf area (cm²)	Number of leaves	Dry mass of stem (g)	Dry mass of leaves (g)
30	32.07[a1]	890.52[a]	12.50[a]	1.62[a]	2.32[a]
10	33.31[a]	974.87[a]	12.06[a]	1.82[a]	2.59[a]
7	30.67[b]	852.61[a]	11.72[a]	1.43[a]	2.35[a]
3	28.89[b]	525.66[b]	10.61[b]	0.89[b]	1.42[b]
0	22.69[c]	510.61[b]	9.94[c]	0.78[b]	1.24[b]
CV (%)	10.86	4.58	2.93	16.36	13.52
F (block)	2.36[ns]	0.50[ns]	2.61[ns]	1.09[ns]	2.84[ns]
F (treatment)	21.25[**]	28.33[**]	30.35[**]	13.46[**]	15.41[**]

** $P<0.01$. ns $P>0.05$. ¹ Within a column, means followed by the same letter are not significantly different according to Scott Knott's F-protected test at P=0.05.

Generally, the periods of 30, 10 and 7 days between cover crop desiccation and sunflower sowing did not produce developmental injuries. Tesfamariam et al. (2009) found similar results, no effect was found for the periods of 21 and 7 days, but development was reduced in the crop sown at 0 days.

At sunflower harvesting, the features of plant height and capitulum diameter did not differ between the treatments (Table 2). The stem diameter and the achene production were both reduced when there was 0 or 3 days between the crop desiccation and the sunflower sowing. These shorter periods caused a reduction of approximately 30% when compared to the desiccation periods greater than 7 days.

Table 2. Height, stem diameter, capitulum diameter and achene production of sunflower at harvest; the crop was sown under different periods after cover crop desiccation.

Periods	Height (cm)	Stem diameter (cm)	Capitulum diameter (cm)	Achene production (kg ha^{-1})
30	210.33[a1]	14.16[a]	14.11[a]	1722.88[a]
10	211.13[a]	14.49[a]	14.49[a]	1828.41[a]
7	209.07[a]	13.81[a]	13.81[a]	1765.65[a]
3	206.33[a]	13.41[b]	13.55[a]	1291.23[b]
0	205.03[a]	13.11[b]	13.00[a]	1263.00[b]
CV (%)	1.66	2.93	2.93	11.53
F (blocks)	0.24[ns]	5.10[*]	4.36[ns]	0.54[ns]
F (treatment)	1.72[ns]	5.62[*]	7.57[**]	6.84[*]

* $P<0.05$. ** $P<0.01$. ns $P>0.05$. ¹ Within a column, means followed by the same letter are not significantly different according to Scott Knott's F-protected test at P=0.05.

The results of achene production showed exponential behavior when evaluated in a quantitative manner (Figure 2). The shortening of the period between *U. ruziziensis* desiccation and sunflower sowing exponentially reduced the achene production. The data presented show an abrupt downward curve caused by the substantial difference in achene production between the plants from the period of 3 and 7 days. Accepting a loss of 5% on achene production, the cover desiccation should be performed in a period of at least 8 days before the no-till sowing of sunflower crops.

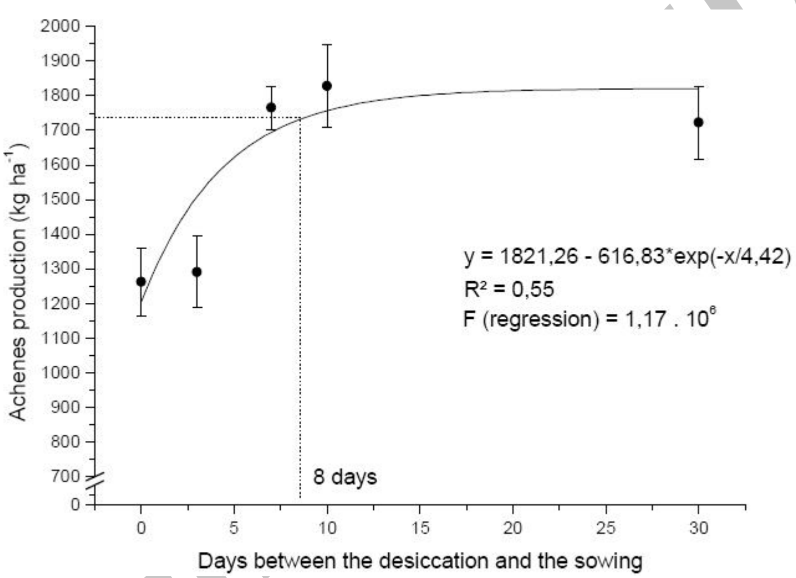

Figure 2. Achene production (kg ha^{-1}) of sunflower sown at increasing days after cover crop desiccation.

Pot assay

35 DAS sunflowers sown at the periods of 3 or 0 days after crop desiccation presented reduced leaf area and fewer leaves than the plants sown at longer periods and when compared to the controls (Table 3). Sunflower plants from the control and from the longer desiccation periods had greater leaf areas and more leaves. The plants sown at the three shorter desiccation periods showed less dry mass of stems. There were no differences in the dry mass of leaves or stem diameter between treatments.

Table 3. Height, number of leaves, leaf area, stem diameter and dry mass of stems and leaves of sunflower evaluated 35 days after sowing under different periods after cover crop desiccation.

Periods	Height (cm)	Number of leaves	Leaf area (cm²)	Stem diameter (mm)	Stem dry mass (g)	Dry mass of leaves (g)
20 days	38.75[a1]	10.00[a]	536.39[a]	6.94[a]	2.39[a]	2.11[a]
15 days	35.12[b]	9.62[a]	480.70[a]	6.25[a]	2.11[a]	1.94[a]
10 days	35.25[b]	9.62[a]	427.09[a]	6.33[a]	1.91[a]	1.86[a]
7 days	35.18[b]	9.75[a]	384.72[a]	6.36[a]	1.77[b]	1.65[a]
3 days	35.00[b]	8.87[b]	276.66[b]	5.66[a]	1.52[b]	1.45[a]
0 day	28.32[c]	8.37[b]	264.94[b]	5.59[a]	1.29[b]	1.35[a]
Control	41.00[a]	10.87[a]	509.68[a]	7.11[a]	2.32[a]	2.22[a]
CV (%)	10.53	11.81	33.16	16.41	33.35	40.13
F	8.87[**]	3.98[**]	5.06[**]	2.46[ns]	3.32[**]	1.65[ns]

[**] $P<0.01$. [ns] $P>0.05$. [1] Within a column, means followed by the same letter are not significantly different according to Scott Knott's F-protected test at $P=0.05$.

At harvest, the control and the plants in treatments with the three longer periods between *U. ruziziensis* desiccation and sunflower sowing showed higher dry mass of leaves and larger capitulum diameters (Table 4). Diameter and dry mass of stems was lower in plants corresponding to the two shorter time periods. This was true for achene productivity as well. These treatments did not differ from those of the control for plant height and sunflower dry mass. Sunflower showed higher achene production when the period between the desiccation and the sowing was equal to or greater than 7 days and these treatments did not differ from the control. When sowing was simultaneous with desiccation or desiccation period was only 3 days, productivity was reduced by 36 and 29%, respectively, when compared to a desiccation period of 15 days.

Results of achene production showed exponential behavior when evaluated in a quantitative manner (Figure 3). As the period between *U. ruziziensis* desiccation and sunflower sowing was shortened, more expressive was the reduction in the sunflower achene production. The regression showed a steeper slope of the curve when compared with those found in the field assay. This can be explained because of the higher number of points on the graphic in this greenhouse assay. Accepting a loss of 5% of achene productivity, the cover crop desiccation should be performed for a period of at least 13 days before the no-tillage sowing.

Table 4. Height, leaf dry mass, stem diameter, stem dry mass, capitulum diameter, capitulum dry mass and achene production of sunflower at harvest; the crop was sown under different periods after cover crop desiccation.

Periods	Height (cm)	Leaf dry mass (g)	Stem diameter (mm)	Stem dry mass (g)	Capitulum diameter (cm)	Capitulum dry mass (g)	Achene production (kg ha^{-1})
20 days	118.75[a1]	8.32[a]	12.38[a]	16.02[a]	9.94[a]	15.04[a]	1314.56[a]
15 days	117.25[a]	8.28[a]	12.41[a]	16.51[a]	9.87[a]	15.07[a]	1341.39[a]
10 days	119.12[a]	7.59[a]	12.20[a]	14.83[a]	9.81[a]	13.69[a]	1227.66[a]
7 days	117.12[a]	6.93[b]	11.38[a]	14.60[a]	8.69[b]	12.99[a]	1173.15[a]
3 days	114.12[a]	5.79[b]	10.30[b]	12.23[b]	8.52[b]	11.50[a]	952.09[b]
0 day	110.50[a]	5.82[b]	10.17[b]	10.96[b]	8.25[b]	11.45[a]	856.57[b]
control	115.50[a]	8.11[a]	12.65[a]	15.16[a]	10.00[a]	14.18[a]	1304.44[a]
CV (%)	4.88	19.75	12.57	22.03	15.79	24.6	24.04
F	2.25[ns]	4.75[**]	4.04[**]	3.26[**]	2.17[*]	1.68[ns]	3.68[**]

[*] $P<0.05$. [**] $P<0.01$. [ns] $P>0.05$. [1] Within a column, means followed by the same letter are not significantly different according to Scott Knott's F-protected test at P=0.05.

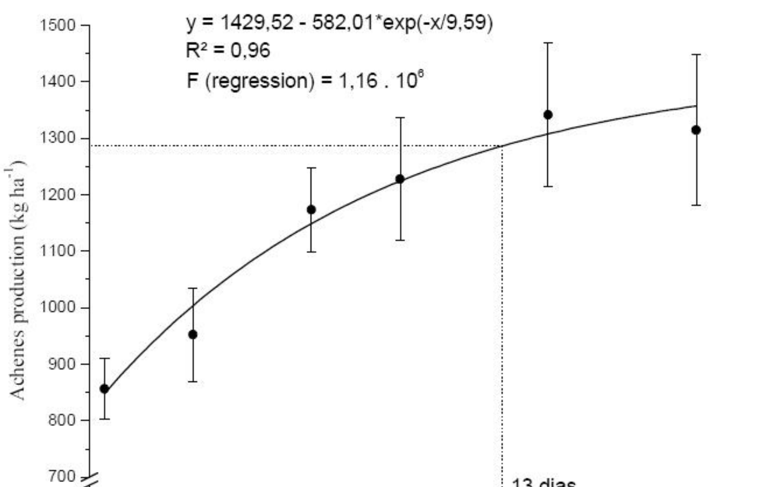

Figure 3. Achene production (kg ha^{-1}) of sunflower sown at increasing days after cover crop desiccation.

Discussion

Inhibitor effects, provided by desiccated cover crops to next crop planted, varies based with time between crop sowing and cover crop desiccation. According to Santos et al. (2007) a period of less than 7 days between *U. ruziziensis* desiccation and soybean sowing reduces crop development. In our study, there was no reduction in productivity when the period between the cover crop desiccation and the crop sowing was equal to or greater than 7 days. This finding did not totally agree with the results presented by Nepomuceno et al. (2012) for soybean crops in the field. However, they found that crop desiccation at the same day as the sowing is harmful, resulting in a productivity reduction of about 30%.

Protodioscin is an allelopathic substance present in plants of the *Urochloa* genus (Assumaidaee and Mustapha, 2012). It is a saponin, which is easily leached from the soil by rain. This substance may cause the deleterious effects found in sunflowers sown at the periods of 3 and 0 days after desiccation. During those days, there was no rain in the field assay. Therefore, the protodioscin could be preserved until the following rain, when the sunflower was germinated and absorption of the allelochemical would be possible. At the period of 7 days between desiccation and sowing, in which there was no observed reduction in achene production, there was rainfall in the amount of 27.6 mm. This rainfall may have leached the allelopathic substance from the soil. Additionally, the time that passed until the sunflower germination may have been enough for the allelochemical to degrade.

Glyphosate is an extremely hydrosoluble herbicide that penetrates quickly into plant cuticles and even days after its application, can continue to be absorbed by plants (Carvalho et al., 2012). Therefore, as there was no rain for the periods of desiccation shorter than 3 days, we may conclude that the herbicide could be preserved in the *U. ruziziensis* cuticle until sunflower crop germination. Then, with the rain, the glyphosate could be made available and absorbed by the sunflower crop, causing the observed developmental and productivity injuries.

Neumann et al. (2006) reported that after glyphosate is absorbed by the target plants, it is quickly translocated from leaves to roots. Then, the herbicide is released into the rhizosphere, where it can be available for a period of time enough to be absorbed by nearby sunflower seedlings. This may have occurred in the present experiment, explaining the productivity reduction for sunflowers sown in shorter periods (3 and 0 days) between the cover crop desiccation and sunflower sowing. Glyphosate is quickly adsorbed by clay mineral particles of soil, rendering it inactive (Zhou et al., 2004). In this study, for the longer periods (7, 10 and 30 days) between desiccation and sunflower sowing, the herbicide did not cause any reduction effect on the sunflowers. It is possible that most of the glyphosate had already been translocated in *U. ruziziensis*, released into the rhizosphere and been adsorbed at clay minerals in the soil.

The results of achene production are in agreement with those of Santos et al. (2007), where it was found that *Urochloa* desiccation and crop sowing in a period less than 7 days reduced soybean development. In that same period of time, Nepomuceno et al. (2012) found a reduction in soybean productivity. These results were confirmed with a sunflower crop as well, in both pots and field assays.

In conclusion, the desiccation of *U. ruziziensis* (with glyphosate at 1.08 kg a. e. ha^{-1} and the dry matter of the cover crop at 6-7 t ha^{-1}) for a period equal to or shorter than three days before the no-tillage sowing of sunflower causes a reduction in sunflower crop development and productivity.

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