e-ISSN 1983-4063 - *www.agro.ufg.br/pat* - Pesq. Agropec. Trop., Goiânia, v. 45, n. 3, p. 274-281, Jul./Sep. 2015

Control of volunteer soybean plants in sunflower crop[1]

Alexandre Magno Brighenti[2]

ABSTRACT

Sunflower (*Helianthus annuus*) sown offseason, after soybean crop (*Glycine max*), is affected by the competition imposed by volunteer plants. Two experiments were carried out to evaluate the control of volunteer soybean plants in sunflower crops. The sulfentrazone herbicide (75 g ha^{-1}, 100 g ha^{-1} and 250 g ha^{-1}) causes phytotoxicity to sunflower immediately after application, however, plants recover, with no yield losses. These doses do not cause the total death of volunteer soybean plants, but temporarily paralyzes their growth, avoiding the competition with the sunflower crop. The glufosinate ammonium and ametryn herbicides are effective in controlling volunteer soybean plants, however, symptoms of phytotoxicity in the sunflower crop are high, reflecting in losses of dry weight biomass and crop yield. The other treatments do not provide satisfactory control of volunteer soybean plants and even reduce the sunflower dry weight biomass and yield.

KEY-WORDS: *Helianthus annuus*; *Glycine max*; herbicides.

RESUMO

Controle de plantas voluntárias de soja em cultivo de girassol

O cultivo de girassol (*Helianthus annuus*), semeado na entressafra após a cultura da soja (*Glycine max*), é prejudicado pela competição imposta por plantas voluntárias. Dois experimentos foram conduzidos a fim de avaliar o controle de plantas voluntárias de soja em cultivo de girassol. O herbicida sulfentrazone (75 g ha^{-1}, 100 g ha^{-1} e 250 g ha^{-1}) causa fitotoxicidade ao girassol logo após a aplicação, porém, há recuperação das plantas, sem prejuízo à produtividade da cultura. Essas mesmas doses não causam a morte total das plantas voluntárias de soja, entretanto, paralisam, temporariamente, seu crescimento, evitando a competição com a cultura do girassol. Os herbicidas amônio glufosinato e ametryn são eficazes no controle de plantas voluntárias de soja, contudo, os sintomas de fitotoxicidade na cultura do girassol são elevados, refletindo em perdas de massa de matéria seca e produtividade da cultura. Os demais tratamentos não proporcionam controle satisfatório das plantas voluntárias de soja e ainda causam redução na massa de matéria seca e produtividade do girassol.

PALAVRAS-CHAVE: *Helianthus annuus*; *Glycine max*; herbicidas.

INTRODUCTION

Sunflower is an oil crop with important agronomic characteristics. Its main product is oil with excellent nutritional quality. Furthermore, the grain can be used for human consumption and animal feed, as well as raw material for the production of biodiesel. Also, sunflower is an option for succession or rotation crops in major grain regions of Brazil.

However, there have been many questions about the presence of volunteer soybean that emerges in successive crops. This plant comes from seeds that fall on the ground by natural threshing of the pods (Bond & Walker 2009) or due to losses during crop harvest (Toledo et al. 2008).

The control of this plant is required and regulated by law in several Brazilian States, based on the creation of a host-free period (Seixas & Godoy 2007). Except for the season traditionally used for soybean sowing, the action defines the period of the year when the presence of living soybean plants is not allowed on fields. This practice is considered one of the main strategies for controlling Asian soybean rust (*Phakopsora pachyrhizi*), preventing the survival and spread of the fungus.

Another issue is the emergence of transgenic soybean resistant to glyphosate, demanding considerable changes in the management of volunteer soybean, given that glyphosate is no longer an alternative way of control (Dan et al. 2009). This

1. Manuscript received in Feb./2015 and accepted for publication in Jul./2015 (http://dx.doi.org/10.1590/1983-40632015v4533999).
2. Empresa Brasileira de Pesquisa Agropecuária (Embrapa Gado de Leite), Juiz de Fora, MG, Brasil.
E-mail: alexandre.brighenti@embrapa.br.

fact may be further aggravated, if transgenic soybean plants emerge in other cultures also resistant to glyphosate, for example, cotton (York et al. 2005, Braz et al. 2013) and maize (Dan et al. 2011). In addition, yield losses can occur by competition, due to high population densities of volunteer soybean plants in subsequent crops.

Surveys on weeds were conducted in sunflower crops in the Brazilian Savannah (Brighenti et al. 2003, Adegas et al. 2010). The presence of volunteer soybean plants was observed in all municipalities sampled with a frequency of 0.24, density of 1.48 plants m^{-2} and 13.5 % relative importance index (Brighenti et al. 2003).

Volunteer soybean control becomes even more complex due to the lack of effective and selective herbicides to control broadleaf weeds in sunflower (Santos et al. 2012). Although the most effective and widely used method is the chemical control, there are no herbicides registered for controlling volunteer soybean in sunflower crops. Alachlor, trifluralin, s-metolchlor and fluazifop-p-butyl are registered in Brazil to sunflower crops (Brasil 2014), however, none of them is efficient in controlling volunteer soybean plants.

This study aimed to evaluate the control of volunteer soybean plants in succession of soybean-sunflower by using contact and systemic herbicides.

MATERIAL AND METHODS

Two experiments were carried out under field conditions in two different Brazilian locations: Coronel Pacheco, Minas Gerais State (21º33'22''S and 43º16'15"W) (experiment 1), and Rio Verde, Goiás State (17º47'53''S and 50º55'41"W) (experiment 2).

Both experiments were laid out in a randomized complete block design, with three and four replications for experiments 1 and 2, respectively. Experiment 1 was conducted in vases, with a single vase per plot, while experiment 2 was carried out in the field, with each plot consisting of five rows of 5 m long, with an area of 6 m^2 (1.5 m x 4.0 m).

Experiment 1 - established on June 15th, 2013, with the following treatments: control without application; glufosinate ammonium (100 g ha^{-1} and 200 g ha^{-1}); sulfentrazone (250 g ha^{-1} and 500 g ha^{-1}); ametryn (250 g ha^{-1} and 500 g ha^{-1}); oxyfluorfen (480 g ha^{-1} and 960 g ha^{-1}); carfentrazone-ethyl (20 g ha^{-1} and 40 g ha^{-1}).

Pots with 3 kg capacity were filled with substrate composed of a mixture of soil, manure and sand (1:1:1). Seeds of sunflower (BRS 323) and soybean (Vencedora BRSMG68) were sown in the same pots, maintained on benches exposed to full sun. The pots were watered regularly, keeping the soil moisture close to field capacity. The plants were thinned after emergence, in order to keep four plants of each species per pot. The average values of rainfall and air temperature during the experiment 1 are shown in Figure 1a.

Treatments were applied on July 7th, 2013, with a backpack sprayer pressurized with carbon dioxide and kept at constant pressure (196 kpa), in order to deliver a spray volume of 150 L ha^{-1}. The sprayer bar (0.5 m length) consisted of two flat-fan nozzles (Magnojet BD 110.02), spaced 0.5 m apart. The vases of each treatment were separated from the rest of the experiment for application of the

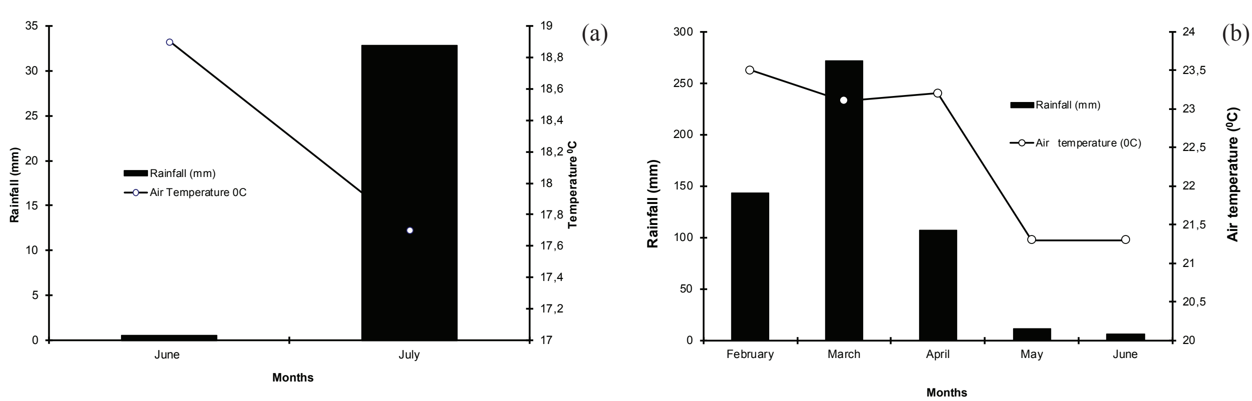

Figure 1. Mean values of rainfall and air temperature during the experiment 1 (a) (Coronel Pacheco, Minas Gerais State, Brazil, 2013) and experiment 2 (b) (Rio Verde, Goiás State, Brazil, 2014).

respective herbicide. Climatic conditions during the herbicide application were as it follows: temperature of 28 ºC, relative humidity of 67 % and wind speed of 2.5 m s^{-1}.

The phenological stages at the application time were V_2 (Castiglioni et al. 1997) and V_1 (Fehr et al. 1971), respectively for sunflower and volunteer soybean plants. Phytotoxicity percentages on sunflower plants and the percentage of control on volunteer soybean were evaluated at 10 and 20 days after herbicide applications (DAA). It was used a visual scale, with zero corresponding to no visual injury symptoms on sunflower or no soybean control and 100 % corresponding to plant death of sunflower and soybean (SBCPD 1995).

The dry matter production of sunflower and soybean plants were obtained at 21 DAA. The plants of both species were cut in each pot. Fresh matter of roots and shoots were placed in kraft paper bags and dried in a forced ventilation oven at 65 ºC, for 72 hours. The dry matter was measured with a graduated scale.

Experiment 2 - installed on February 27th, 2014, in a complete randomized block design, treating four plots as replications. The treatments were: hoed and unhoed control; glufosinate ammonium (40 g ha^{-1} and 100 g ha^{-1}); sulfentrazone (75 g ha^{-1} and 100 g ha^{-1}); tembotrione (21 g ha^{-1}); carfentrazone (4 g ha^{-1}); saflufenacil (1.75 g ha^{-1} and 3.5 g ha^{-1}); triclopyr (120 g ha^{-1}); and MSMA (197.5 g ha^{-1}).

Sunflower was sown in an area where soybean had been harvested. Each plot consisted of five rows of 5 m long (10 m^2), with a net area of 6 m^2 (1.5 m x 4.0 m). The sunflower hybrid BRS 323 was sown in rows 0.5 m apart, with a plant stand of approximately 55,000 plants ha^{-1}. The fertilization at sowing time consisted of 400 kg ha^{-1} of NPK (08-20-18). Nitrogen (50 kg ha^{-1}) and boron (1.2 kg ha^{-1}) side dressing were performed at 25 days after sowing (DAS). The average values of rainfall and air temperature during the experiment 2 are shown in Figure 1b.

Treatments were applied on March 18th, 2014, using a backpack sprayer pressurized by compressed CO_2 (196 kpa) with a bar of 1.5 m length, equipped with four flat-fan nozzles (Magnojet 110.01 BD), spaced 0.5 m apart, and a spraying volume equivalent to 80 L ha^{-1}.

Environmental conditions during the pulverization were: wind speed of 3 m s^{-1}, temperature of 29 ºC and relative humidity of 65 %. The phenological stages of sunflower and soybean plants at the application time were respectively V_4 (Castiglioni et al. 1997) and V_3 (Fehr et al. 1971).

The phytotoxicity percentages on sunflower plants and the percentage of volunteer soybean control were evaluated at 7, 14 and 21 DAA, with zero corresponding to no visual injury symptoms on sunflower or no soybean control and 100 % corresponding to plant death of sunflower and soybean (SBCPD 1995).

Volunteer soybean plants were cut inside a square of 0.5 m x 0.5 m (0.25 m^2), at 120 days after sowing, and dried in a forced air ventilation oven at 65 ºC, during 72 hours, to constant mass. The number of achenes per plant, plant height and weight of one thousand achenes were determined at harvest time. Plant stand and sunflower yield were obtained in an area of 6 m^2, with results turned into plants ha^{-1} and kg ha^{-1}, respectively. Data obtained for dry matter of volunteer soybean plants were subjected to transformation (log x), in order to complete the analysis of variance.

Data were submitted to Anova and means compared by the Scott-Knott test ($p \leq 0.05$), for both experiments (Ribeiro Júnior 2001).

RESULTS AND DISCUSSION

The percentages of phytotoxicity on sunflower plants and control of volunteer soybean at 10 and 20 DAA, as well as dry weight biomass of sunflower and soybean plants, concerning the treatments for the experiment 1, conducted in Coronel Pacheco, are shown in Tables 1 and 2.

Glufosinate ammonium, ametryn and carfentrazone provided high phytotoxicity values in sunflower plants, while the other treatments caused initial phytotoxicity with subsequent recovery of plants (Table 1).

The best levels for controlling voluntary soybean plants were obtained with the application of glufosinate ammonium, ametryn and oxyfluorfen (Table 1).

Sulfentrazone (250 g ha^{-1}) had no effect on sunflower dry weight matter and provided reduction on volunteer soybean biomass (Table 2). The other herbicides affected sunflower plants, reaching values statistically different from the control without application. Regarding the dry weight of soybean plants, all treatments reduced soybean biomass.

Table 1. Phytotoxicity percentage on sunflower plants and volunteer soybean control at 10 and 20 days after application (DAA), for treatments in the experiment 1 (Coronel Pacheco, Minas Gerais State, Brazil, 2013).

Treatment	Dose (g ha^{-1})	Phytotoxicity percentage 10 DAA	Phytotoxicity percentage 20 DAA	Soybean control 10 DAA	Soybean control 20 DAA
Control without application	-	0.0	0.0	0.0	0.0
Glufosinate ammonium	100	40.0	91.0	58.3	80.0
Glufosinate ammonium	200	58.3	97.6	86.6	93.3
Sulfentrazone	250	11.3	0.0	18.3	15.0
Sulfentrazone	500	16.6	13.0	28.3	61.6
Ametryn	250	9.3	100.0	95.0	100.0
Ametryn	500	15.0	100.0	90.0	100.0
Oxyfluorfen	480	40.0	11.3	78.3	71.6
Oxyfluorfen	960	45.3	11.3	81.6	78.6
Carfentrazone	20	35.0	66.6	20.0	2.0
Carfentrazone	40	48.3	72.6	25.0	2.0

Table 2. Dry weight biomass of sunflower and soybean plants (g pot^{-1}) at 21 DAA, for treatments in the experiment 1 (Coronel Pacheco, Minas Gerais State, Brazil, 2013).

Treatment	Dose (g ha^{-1})	Dry weight biomass of sunflower	Dry weight biomass of soybean
Control without application	-	9.6 A[1]	11.5 A
Glufosinate ammonium	100	4.8 B	8.2 B
Glufosinate ammonium	200	0.9 B	2.9 D
Sulfentrazone	250	9.2 A	9.2 B
Sulfentrazone	500	5.5 B	8.1 B
Ametryn	250	3.1 B	0.8 E
Ametryn	500	2.0 B	0.8 E
Oxyfluorfen	480	5.3 B	3.9 D
Oxyfluorfen	960	5.2 B	2.6 D
Carfentrazone	20	5.0 B	8.0 B
Carfentrazone	40	5.4 B	5.9 C
CV (%)	-	42.7	20.2

[1] Means followed by the same letter in each column are not statistically different by the Scott-Knott test ($p \leq 0.05$).

The selection of herbicides to the field experiment 2 was performed according to the results of the experiment 1. It was observed that contact herbicides, such as sulfentrazone, cause the death of sunflower leaves. However, the apical bud was not injured and there was plant recovery. Thereby, besides selecting the best treatments described in experiment 1, other contact herbicides (MSMA and saflufenacil) were added to the field study (experiment 2). Tembotrione and triclopyr were also applied and, even though they are not contact herbicides, they are effective in the Fabaceae weed control. In addition, tembotrione and saflufenacil are registered in Brazil to control volunteer soybean plants (Brasil 2015).

The phytotoxicity percentages on sunflower plants at 7, 14 and 21 DAA, for the experiment 2, are shown in Table 3.

Treatments with glufosinate ammonium caused the greatest injury to sunflower plants. This herbicide acts by contact, changing the metabolism of ammonia (Rodrigues & Almeida 2005). The means obtained in treatments with two doses of this herbicide reached values ranging 72-77 %, at 7 DAA. A significant increase of symptoms was observed on the second visual evaluation, characterized by tissue necrosis (79-80 %). However, there was a slight recovery at 21 DAA (54-60 %).

Sulfentrazone inhibits the activity of the protoporphyrinogen oxidase (Protox) enzyme, accumulating protoporphyrin IX. This molecule interacts with oxygen and light, forming the reactive oxygen, which is capable of causing peroxidation of lipids in cell membranes. Treatments with sulfentrazone caused tissue necrosis, reaching values of 20 % and 45 %, at the first evaluation. However,

Table 3. Phytotoxicity percentage on sunflower plants at 7, 14 and 21 days after application (DAA), for treatments in the experiment 2 (Rio Verde, Goiás State, Brazil, 2014).

Treatment	Dose (g ha^{-1})	Phytotoxicity percentage 7 DAA	Phytotoxicity percentage 14 DAA	Phytotoxicity percentage 21 DAA
Hoed control	-	0	0	0
Unhoed control	-	0	0	0
Glufosinate ammonium	40.00	72	79	54
Glufosinate ammonium	100.00	77	80	60
Sulfentrazone	75.00	20	22	10
Sulfentrazone	100.00	45	30	15
Tembotrione	21.00	34	29	24
Carfentrazone	4.00	78	46	34
Saflufenacil	1.75	47	36	20
Saflufenacil	3.50	76	39	25
Triclopyr	120.00	36	45	35
MSMA	197.50	18	22	19

the apical meristems of sunflower plants were not injured by the herbicide. There was a recovery of the plants, with emergence of new leaves free of the effects caused by sulfentrazone.

The tembotrione herbicide inhibits carotenoid synthesis. The pigment-inhibiting herbicide acts by blocking the formation of carotenoids, resulting in destruction of the chlorophyll by light energy. The new leaves turn white, since there is no pigment synthesis (Oliveira Júnior 2011). The sunflower plant leaves turned white, evolving to dry and dead tissue. The percentage of phytotoxicity was 34 %, at 7 DAA. However, it was observed a reduction on injury symptoms at 21 DAA (24 %).

The application of carfentrazone provided high values of phytotoxicity at 7 DAA (78 %). This herbicide acts by contact, being also a Protox inhibitor. However, there was a recovery of plants, with emergence of new leaves. The phytotoxicity percentage dropped to 34 %, at the last evaluation.

The saflufenacil also inhibits the synthesis of protoporphyrinogen oxidase. The two doses of saflufenacil provided percentages of phytotoxicity ranging from 47 % to 76 %, at 7 DAA. There was a recovery, with emergence of new leaves. The percentages of phytotoxicity decreased to 20-25 %, at 21 DAA.

The triclopyr belongs to the chemical group of growth regulators. This product causes epinasty, inhibition and chlorosis of the growing meristems (Rodrigues & Almeida 2005). The sunflower plants turned twisted and chlorotic, achieving percentage of phytotoxicity of 36 %, at 7 DAA. The values of injury symptoms increased at 14 DAA, reaching 45 %. However, a slight recovery of plant growth was observed at 21 DAA (35 %).

The MSMA is a contact herbicide that belongs to the group of organic arsenicals. However, its mechanism of action is not well defined (Oliveira Júnior 2011). The characteristic symptoms are related to rapid desiccation of leaves and destruction of cell membranes. In the first two evaluations, values ranged from 18 % to 22 % (Table 3). There was a beginning of recovery of plants (19 %), with the emergence of new leaves, at the last evaluation.

The mean values of volunteer soybean control after 7, 14 and 21 DAA and dry weight biomass related to the experiment conducted in Rio Verde are shown in Table 4.

Glufosinate ammonium was the most effective molecule to control volunteer soybean plants. The two doses administered led to control percentages ranging from 84 % to 87 %, at 21 DAA. This herbicide provided excellent levels of control, when applied in the early development of volunteer soybean (Bond & Walker 2009). The glufosinate ammonium, at doses of 300 g ha^{-1}, 400 g ha^{-1} and 500 g ha^{-1}, led to complete death of volunteer soybean plants, when applied on post-emergence of cotton crop (Braz et al. 2013).

Concerning the differential sensitivity to herbicides in soybean and sunflower, soybean is more tolerant than sunflower. Thereby, herbicides that control soybean plants also eliminate completely sunflower plants.

The two doses of sulfentrazone led to soybean control of 16 % and 21 %, in the last evaluation. Those treatments did not cause death of volunteer soybean plants. However, there is a temporary inhibition of growth. This fact mitigates the effects of competition between soybean and sunflower. In addition, smaller leaf area provides worse conditions for soybean Asian rust survival (Calaça 2007).

Tembotrione, carfentrazone, saflufenacil, triclopyr and MSMA were not efficient in controlling volunteer soybean plants. Low percentages of control were also observed when tembotrione was applied on a different volunteer soybean cultivar (Valiosa RR®) (Dan et al. 2009).

MSMA did not control volunteer soybean at the dose of 925 g ha^{-1} (York et al. 2005). Even though there was extensive necrosis of the leaves that had received the product, the emergence of new leaves did not present symptoms of injury.

The application of glufosinate ammonium and sulfentrazone doses led to the lowest dry matter values of volunteer soybean plants (Table 4). The herbicides were applied when volunteer soybean plants were at the V_3 growth stage. Probably, the control levels of these treatments could be higher if the applications were performed in more juvenile stages of the soybean cycle.

Treatments with tembotrione, carfentrazone, saflufenacil, triclopyr and MSMA did not provide efficient control, although a reduction of dry biomass of volunteer soybean was achieved.

The mean values for number of achenes per plant, plant height, weight of one thousand achenes, plant stand and sunflower yield for the experiment conducted in Rio Verde (experiment 2) are shown in Table 5.

Table 4. Percentage of control at 7, 14 and 21 days after application (DAA) and dry weight biomass of volunteer soybean, for the treatments in the experiment 2 (Rio Verde, Goiás State, Brazil, 2014).

Treatment	Dose (g ha^{-1})	Percentage of control 7 DAA	Percentage of control 14 DAA	Percentage of control 21 DAA	Dry weight biomass (g 0.25 m^{-2})
Hoed control	-	100	100	100	42.3 B[1]
Unhoed control	-	0	0	0	226.0 A
Glufosinate ammonium	40.00	68	77	84	8.6 D
Glufosinate ammonium	100.00	78	73	87	5.6 D
Sulfentrazone	75.00	18	17	16	37.0 C
Sulfentrazone	100.00	35	30	21	35.0 C
Tembotrione	21.00	13	11	5	71.0 B
Carfentrazone	4.00	23	13	9	72.0 B
Saflufenacil	1.75	10	9	6	129.7 A
Saflufenacil	3.50	12	10	8	122.2 A
Triclopyr	120.00	15	11	6	121.3 A
MSMA	197.50	17	13	9	78.3 B
CV (%)	-	-	-	-	9.0

[1] Means followed by the same letter in each column are not statistically different by the Scott-Knott test ($p \leq 0.05$).

Table 5. Number of achenes per sunflower plant, plant height, weight of one thousand achenes, sunflower stand and yield, for the treatments in the experiment 2 (Rio Verde, Goiás State, Brazil, 2014).

Treatment	Dose (g ha^{-1})	Number of achenes per plant	Plant height (cm)	Weight of one thousand achenes (g)	Plant stand (plants ha^{-1})	Sunflower yield (kg ha^{-1})
Hoed control	-	757.3 A[1]	184.7 A	53.5 A	55,000.0 A	2,244.7 A
Unhoed control	-	693.7 B	182.5 A	55.3 A	55,416.6 A	2,031.9 B
Glufosinate ammonium	40.00	649.9 B	180.3 A	13.3 B	55,833.3 A	1,940.9 B
Glufosinate ammonium	100.00	673.5 B	182.1 A	28.3 B	54,583.3 A	2,013.6 B
Sulfentrazone	75.00	742.3 A	185.4 A	55.9 A	56,666.6 A	2,339.4 A
Sulfentrazone	100.00	783.2 A	185.2 A	55.2 A	55,000.0 A	2,387.4 A
Tembotrione	21.00	604.0 B	184.8 A	53.5 A	60,000.0 A	1,934.6 B
Carfentrazone	4.00	639.2 B	173.0 B	62.3 A	43,333.3 B	1,735.1 B
Saflufenacil	1.75	729.5 A	183.9 A	55.5 A	45,000.0 B	1,810.0 B
Saflufenacil	3.50	727.8 A	171.9 B	28.5 B	47,916.6 B	2,043.2 B
Triclopyr	120.00	744.8 A	168.0 B	41.3 A	57,500.0 A	2,072.7 B
MSMA	197.50	692.7 B	166.2 B	57.4 A	53,750.0 A	2,030.8 B
CV (%)	-	7.7	5.4	37.5	10.0	12.2

[1] Means followed by the same letter in each column are not statistically different by the Scott-Knott test ($p \leq 0.05$).

The application of glufosinate ammonium reduced the number of achenes per plant, weight of one thousand achenes and sunflower yield; sulfentrazone had no effect on any variable, in comparison to the hoed control; tembotrione reduced the number of seeds per plant and crop yield; carfentrazone caused reduction in all variables, except for weight of one thousand achenes; triclopyr reduced plant height and yield; MSMA decreased the number of achenes, plant height and yield; and the application of two doses of saflufenacil decreased plant stand and sunflower yield, with its highest dose also leading to a reduction in plant height and weight of one thousand achenes.

The effect of competition between volunteer soybean and sunflower was observed when comparing the unhoed and hoed control, with the sunflower crop producing 212 kg ha^{-1} less grains in the unhoed than in the hoed control.

This study provides options for controlling volunteer soybean plants in soybean-sunflower succession. Besides avoiding the competition between soybean and sunflower, other advantage of this management is the suppression of soybean growth, limiting the condition for the Asian rust survival.

CONCLUSIONS

1. Sulfentrazone (75 g ha^{-1}, 100 g ha^{-1} and 250 g ha^{-1}) causes phytotoxicity to sunflower immediately after application, however, there is plant recovery and no yield losses.
2. Sulfentrazone (75 g ha^{-1}, 100 g ha^{-1} and 250 g ha^{-1}) does not cause the total death of volunteer soybean plants, but temporarily paralyzes their growth, avoiding competition with the sunflower crop.
3. Glufosinate ammonium and ametryn are effective in controlling volunteer soybean plants. However, symptoms of phytotoxicity in the sunflower crop are high, reflecting in losses of dry weight biomass and crop yield.

ACKNOWLEDGMENTS

This study was supported by the Fundação de Amparo à Pesquisa do Estado de Minas Gerais (Fapemig) and Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq).

REFERENCES

ADEGAS, F. S. et al. Levantamento fitossociológico de plantas daninhas na cultura do girassol. *Planta Daninha*, Viçosa, v. 28, n. 4, p. 705-716, 2010.

BOND, J. A.; WALKER, T. W. Control of volunteer glyphosate resitant-soybean in rice. *Weed technology*, Fayetteville, v. 23, n. 2, p. 225-230, 2009.

BRASIL. Ministério da Agricultura, Pecuária e Abastecimento. *Agrofit*: consulta de produtos formulados. 2014. Available at: <http://extranet.agricultura.gov.br/agrofit_cons/principal_agrofit_cons>. Access on: 09 Sep. 2014.

BRASIL. Ministério da Agricultura, Pecuária e Abastecimento. *Agrofit*: consulta de produtos formulados. 2015. Available at: <http://agrofit.agricultura.gov.br/agrofit_cons/principal_agrofit_cons>. Access on: 26 Jun. 2015.

BRAZ, G. B. P. et al. Alternativas para o controle de soja RR voluntária na cultura do algodoeiro. *Bioscience Journal*, Uberlândia, v. 29, n. 2, p. 360-369, 2013.

BRIGHENTI, A. M. et al. Cadastramento fitossociólogico de plantas daninhas na cultura do girassol. *Pesquisa Agropecuária Brasileira*, Brasília, DF, v. 38, n. 5, p. 651-657, 2003.

CALAÇA, H. A. *Ferrugem asiática da soja*: relações entre o atraso do controle químico, rendimento, severidade e área foliar sadia de soja (*Glycine max*). 2007. 80 f. Tese (Mestrado em Agronomia) - Escola Superior de Agricultura Luiz de Queiroz, Universidade de São Paulo, Piracicaba, 2007.

CASTIGLIONI, V. B. R. et al. *Fases de desenvolvimento da planta de girassol*. Londrina: Embrapa-CNPSo, 1997. (Documentos, 59).

DAN, H. A. et al. Controle químico de plantas voluntárias de soja Roundup Ready®. *Revista Brasileira de Herbicidas*, Maringá, v. 8, n. 3, p. 96-101, 2009.

DAN, H. A. et al. Controle de plantas voluntárias de soja com herbicidas utilizados em milho. *Revista Brasileira de Ciências Agrárias*, Recife, v. 6, n. 2, p. 253-257, 2011.

FEHR, W. R. et al. Stage of development descriptions for soybean, *Glycine max* (L.) Merrill. *Crop Science*, Madison, v. 11, n. 6, p. 929-931, 1971.

OLIVEIRA JÚNIOR, R. S. O. Mecanismos de ação de herbicidas. In: OLIVEIRA JÚNIOR, R. S. O.; CONSTANTIN, J.; INOUÊ, M. H. *Biologia e manejo de plantas daninhas*. Curitiba: Omnipax, 2011.

RIBEIRO JÚNIOR, J. I. *Análises estatísticas no SAEG*. Viçosa: UFV, 2001.

RODRIGUES, B. N.; ALMEIDA, F. S. *Guia de herbicidas*. 5. ed. Londrina: Grafmarke, 2005.

SANTOS, G. et al. Uso do novo sistema clearfield® na cultura do girassol para controle de plantas daninhas dicotiledôneas. *Planta Daninha*, Viçosa, v. 30, n. 2, p. 359-365, 2012.

SEIXAS, C. D. C.; GODOY, C. V. Vazio sanitário: panorama nacional e medidas de monitoramento. In: SIMPÓSIO BRASILEIRO DE FERRUGEM ASIÁTICA DA SOJA, 2007, Londrina. *Anais*... Londrina: Embrapa Soja, 2007. p. 21-31.

SOCIEDADE BRASILEIRA DA CIÊNCIA DAS PLANTAS DANINHAS (SBCPD). *Procedimentos para instalação e análise de experimentos com herbicidas*. Londrina: SBCPD, 1995.

TOLEDO, A. et al. Caracterização das perdas e distribuição de cobertura vegetal em colheita mecanizada de soja. *Engenharia Agrícola*, Jaboticabal, v. 28, n. 4, p. 710-719, 2008.

YORK, A. C.; BEAM, J. B. B.; CULPEPPER, A. S. Control of volunteer glyphosate resistant-soybean in cotton. *Journal of Cotton Science*, Cordova, v. 9, n. 1, p. 102-109, 2005.