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RESEARCH ARTICLE

WEED CONTROL AND SELECTIVITY OF ALTERNATIVE HERBICIDES TO GLYPHOSATE IN SOY CULTIVATION

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ABSTRACT

One of the main alternatives found by producers for mitigating the problems caused by the occurrence of resistant weed biotypes is the use of alternative herbicides. The aim of this paper was to evaluate weed control and the phytotoxicity caused by the application of pre-and post-emergent herbicides in soy cultivars that are resistant to glyphosate. Two field experiments were carried out in a random block experimental design, with four repetitions. The treatments were arranged in a factorial design, testing two soy cultivars (Nidera 5909 RG and Coodetec STS 249 RR), four pre-emergent herbicides (s-metolachlor, diclosulan, metribuzin, sulfentrazone) and four post-emergent herbicides (chlorimuron ethyl, imazethapyr, bentazone, carfentrazone ethyl), plus infested and clean samples. Phytotoxicity evaluations of the crop were carried out 7, 14, and 21 days after the emergence (DAE) of soy plants for the pre-emergents; and 7, 14, and 21 days after the application of the herbicides (DAA) for the post-emergents. The weed control evaluation for both experiments was carried out at 14 and 28 DAE, with the exception of *Ipomoea* spp., at 14 DAE. In pre-emergence, sulfentrazone causes greater phytotoxicity in both cultivars studied, while in post-emergence, carfentrazone ethyl causes the greatest symptoms of phytotoxicity. In pre-emergence, the best *Raphanus* spp. and *Bidens* spp. controls were obtained with the application of the herbicides diclosulan and metribuzin, while sulfentrazone and diclosulan provide the best *Ipomoea* spp. controls. The herbicide sulfentrazone reduces the productivity of the Nidera 5909 RG cultivar, while carfentrazone reduces the productivity of both cultivars.

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INTRODUCTION

Glycine max (L.) Merrill soy constitutes one of the main agricultural crops in Brazil, with total production in 2015-16 of more than 95 million tones of grain from a harvest area of approximately 33 million hectares (Conab, 2016). Brazil is the second biggest producer and exporter of grain in the world, surpassed only by the United States (Fao, 2016). Out of the Brazilian states, Rio Grande do Sul (RS) has the third highest production, after Mato Grosso and Paraná, and represents approximately 17% of soy production in the country (Ibge, 2016). On the other hand, productivity in RS, at 2,970kg ha^{-1}, could be considered low, since it is around 15% lower than productivity in Mato Grosso, the most productive state in the previous harvest (Ibge, 2016). Soy cultivation can be affected by various factors, such as: farming systems, unfavorable environments, and inadequate crop and pest management practices. Among the pests, weeds stand out by competing for resources that are essential for development, such as water, light, nutrients, and CO_2, with such interference causing up to 93% direct damage to soy productivity (Silva *et al*., 2009). To minimize the negative effects of competition, crops should be kept free from the presence of weeds, and management strategies that aim to control them need to be adopted. Chemical management of weeds in soy crops has been made easier since the introduction of genetically modified soy that is resistant to the herbicide glyphosate (Roundup Ready®). Glyphosate is a systemic herbicide, which inhibits the 5-enolpiruvylshikimate-3-phosphate synthase enzyme (EPSPs), stopping the synthesis of aromatic amino-acids (triptophane, phenylalanine, and tyrosine), as well as the

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production of alkaloids, flavonoids, lignine, and phenolic compounds, which can represent up to 35% of vegetal biomass, among other compounds (Roman *et al*., 2007; Velini *et al*., 2009). This herbicide is characterized as not being selective and as acting systemically, and is widely used in mono and dicotyledonous weed control (Roman *et al*., 2007). However, the exclusive adoption of glyphosate continuously and for more than two crop cycles has resulted in resistant weeds being selected (Vargas *et al*., 2013; Ulguim *et al*., 2013). Resistance is defined as the inherent and inheritable ability of a biotype within a particular population to survive and reproduce after exposure to a recorded dose of herbicide, which is normally lethal to the susceptible population of the same species (Gazziero *et al*., 2014). Reports currently exist of 470 weed biotypes that are resistant to herbicides in the world, and of these, ALS (acetolactate synthase) inhibiting, FSII (photosynthesis II) inhibiting, and ACCase (Acetyl-Coenzyme A carboxylase) inhibiting herbicides are the most recorded, with 159, 73, and 48 resistant biotypes, respectively (Heap, 2016). For EPSP inhibiting herbicides, resistance in 35 species in the world is reported. In Brazil, there are eight species of weeds that are resistant to the herbicide glyphosate, these being: *Lolium perene* ssp. *multiflorum, Conyza bonariensis*, *Conyza canadensis*, *Digitaria insularis, Conyza sumatrensis, Chloris elata, Amaranthus palmeri* and *Eleusine indica* (Heap, 2016).

Rotation of herbicides with different action mechanisms is one of the main practices that aim to reduce cases of resistance evolving, as well as being efficient for the management of resistant weeds (Beckie, 2011). Thus, it is important that, even in crops that are resistant to glyphosate, producers make use of integrated weed management, using alternative herbicides, crop rotation, and crop cover in order to reduce the damage caused by resistance (Cerdeira *et al*., 2011). The application of ammonium gluphosinate isolated and/or mixed with other herbicides has provided satisfactory control of *Conyza* spp. biotypes that are resistant to glyphosate in the pre-flowering stage (Moreira *et al*., 2010). Effective control of *Conyza sumatrensis* biotypes that are resistant to glyphosate has been observed from isolated application of the herbicides 2.4-D, ammonium gluphosinate, and tembotrione, as well as mixtures of glyphosate + 2.4-D, paraquat + diuron, and tembotrione + atrazine (Santos *et al*., 2015). It is important to highlight that substitution of the currently used herbicide is only possible if the alternative herbicides allow for satisfactory weed control, but without negatively affecting crop growth and/or development (Peterson, 1999). As proof of this, the application of the herbicides lactofen and flumioxazin provided satisfactory weed control, but caused significant phytotoxicity in soy crops (Correia *et al*., 2008). In light of the above, the aim of this study was to evaluate weed control and the phytotoxicity caused by the application of pre-and post-emergent herbicides in soy cultivars that are resistant to glyphosate.

MATERIAL AND METHODS

Two experiments were carried out at the Palm Agricultural Center, which belongs to the Federal University of Pelotas (*UFPel*), in the municipality of Capão do Leão, in the state of Rio Grande do Sul, in a random block experimental design, with four repetitions. The treatments were arranged in a factorial design, with two soy cultivars (Nidera 5909 RG and Coodetec STS 249 RR), four pre-emergent (experiment 1) and four post-emergent herbicides (experiment 2), plus infested and clean samples (Table 1). Each herbicide's characteristics and the doses used are presented in Table 1 (Agrofit, 2016). The soil in the experimental area is classified as Red-Yellow Agrisoil, of a sandy-clayey texture, belonging to the Pelotas mapping unit (Table 2). The soil correction fertilization was carried out by manually raking, based on previous analysis of it, using 260 Kg ha^{-1} of 02-20-20 (N-P-K) formula fertilizer. The experimental units were composed of an area of 14.0 m² (5.0 m x 2.8 m). To desiccate the vegetation present in the experimental area, Atanor®glyphosate herbicide was applied on December 20, 2013, distributing 16 seeds per meter, with a 40 cm space between lines and 2.5 cm deep seed deposition. The emergence of soy seedlings occurred on December 27, 2013.

Table 1. Trade name, concentration, active ingredient and rate of the herbicides pre (experiment 1) or post-emergents (experiment 2) used in the treatments

Trade name	Concentration	Active ingredient	Rate[1]
Herbicides pré-emergents (Experiment1)			
Control (clean)	-	-	-
Control (infested)	-	-	-
Dual gold®	960 g L^{-1}	S-metolachlor	1920.0 g
Spider® 840 WG	840 g Kg^{-1}	Diclosulan	33.6 g
Sencor® 480	480 g L^{-1}	Metribuzin	480.0 g
Boral® 500 SC	500 g L^{-1}	Sulfentrazone	600.0 g
Herbicides post-emergents (Experiment2)			
Control (clean)	-	-	-
Control (infested)	-	-	-
Classic®	250 g Kg^{-1}	Chlorimuron ethyl	20.0 g
Pivot®	10 g L^{-1}	Imazethapyr	100.0 g
Basagran® 600	600 g L^{-1}	Bentazon	720.0 g
Aurora® 400 EC	400 g L^{-1}	Carfentrazone ethyl	30.0 g

[1]Active ingredient per hectare (herbicide maximum label rate to soybean crop).

The pre-and post-emergent herbicides were applied on December 23, 2013 and January 17, 2014, respectively. To apply the Classic® and Aurora® 400 EC herbicides, Assist® mineral oil was added to the spray mixture in 0.5% v/v doses. For the poaceae species control, Select® 240 EC herbicide was applied in 170 g i.a ha^{-1} doses, plus Assist® mineral oil in 0, 5% v/v doses, 18 days after the soy seedlings emerged (DAE). To apply the herbicides, a CO_2 pressurized costal sprayer was used, equipped with a rod containing four spraying points (XR TeeJet®), from the 110.02 series, calibrated to a pressure of 30 psi and allowing 120 L ha^{-1} of herbicide mixture to be applied. In the "clean" samples, manual hoeing and uprooting of the weeds was carried out. The predominant weeds in the experimental area were: *Raphanus* spp., *Bidens* spp., and *Ipomoea* spp., in average populations of 10, 28, and 29 plants m^{-2}, respectively. The variables evaluated in the field were crop phytotoxicity of the soy plants at 7, 14, and 21 DAE for the pre-emergents, and 7, 14, and 21 days after the herbicides were applied (DAA) for the post-emergents. The weed control evaluation for both of the experiments was carried out at 14 and 28 DAE, with the exception of *Ipomoea* spp. at 14 DAE, for the pre-emergents, due to the inexistence of seedlings from this species on the date of evaluation. The phytotoxicity or the control were visually evaluated, using a percentage scale, where zero (0%) corresponded to no

Table 2. Chemical soil characteristics of the experimental area

Organic matter percentage (m v^{-1})	Clay percentage (m v^{-1})	Texture	P-Mehlich	K	pHH_2O 1:1	SMP index
			mg dm^{-3}			
1.8	16	4	16	57	6.3	6.9
CEC pH 7.0	CEC efective	Ca	Mg	Al	H+Al	
---cmol$_c$dm^{-3}---						
7.7	6.1	4.2	1.8	0.0	1.6	

phytotoxic effect on the crop or weed control, and one hundred (100%) referred to total death of the crop or weeds. Plant collection occurred at 144 DAE, in a useful area of 3.6 m^2, with the values being subsequently transformed into Kg ha^{-1}, and grain humidity corrected to 13%. The data obtained for all of the variables were analyzed with regards to normality and homoscedasticity, and were subsequently submitted to variance analysis using the F test ($p \leq 0.05$). With significance occurring between the treatments, the effects of the cultivars were compared using the Student test ($p \leq 0.05$), and the effects of the herbicides using the Duncan test ($p \leq 0.05$).

RESULTS AND DISCUSSION

For the pre-emergent herbicides, interaction was verified between the factors for the phytotoxicity variables at 7; 14 and 21 DAE, *Bidens* spp. control at 28 DAE, and grain productivity. The effect of herbicide was observed in the variables, *Bidens* spp. control at 14 DAE, *Raphanus* spp. control at 14 and 28 DAE, and *Ipomoea* spp. control at 28 DAE. No isolated cultivar effect was observed for any of the variable evaluated. The herbicide sulfentrazone caused greater phytotoxicity in soy cultivars in all of the evaluation periods, compared to the other treatments and control samples (Table 3). The symptoms of phytotoxicity for sulfentrazone differed between the two cultivars in all of the evaluations, except at 7 DAE, with more intense symptoms observed in the Nidera 5909 RG cultivar, in comparison with Coodetec STS 249 RR.

Table 3. Phytotoxicity of soybean cultivars Nidera 5909 RG (NA) and Coodetec STS 249 RR (CD) at 7 ($P_{07\ DAE}$); 14 ($P_{14\ DAE}$) and 21 DAE ($P_{21\ DAE}$), as affected by application of different herbicides in pre emergency

Treatment	Phytotoxicity (%)					
	$P_{07\ DAE}$[1]		$P_{14\ DAE}$		$P_{21\ DAE}$	
	NA	CD	NA	CD	NA	CD
Control (clean)	0.0 c^{ns2}	0.0 d	0.0 c^{ns}	0.0 c	0.0 c^{ns}	0.0 d
Control(infested)	0.0 c^{ns}	0.0 d	0.0 c^{ns}	0.0 c	0.0 c^{ns}	0.0 d
S-metolachlor	9.3 b^{ns}	10.5 b	5.3 b^{ns}	5.8 b	2.8 c*	0.8 d
Diclosulan	3.8 c^{ns}	3.8 c	5.5 b^{ns}	5.5 b	10.0 b*	6.8 b
Metribuzin	11.0 b^{ns}	8.5 b	5.5 b^{ns}	5.3 b	3.5 c^{ns}	3.5 c
Sulfentrazone	25.5 a^{ns}	16.3 a	62.5 a*	22.0 a	40.5 a*	28.5 a
C.V. (%)	35.74	22.33	25.50	18.17	31.98	31.28

[1]Days after emergency of soybean plants; [2]Means followed by same letter, in the column, compare herbicides inside of cultivar by Duncan's test ($p \leq 0.05$), and * (significative) or ^{ns} (non significative) in the line compare cultivars effect inside of herbicides factor by t test ($p \leq 0.05$).

When the herbicide sulfentrazone is applied in pre-emergence, on emerging the plants enter into contact with it and their tissue is damaged. The selectivity of sulfentrazone is highly related with the plants' ability torapidly metabolize the herbicide molecule (Arruda *et al*., 1999). Thus, the Nidera 5909 RG cultivar possibly metabolizes the sulfentrazone herbicide more slowly in relation to Coodetec STS 249 RR, and therefore this herbicide causes greater phytotoxicity.

Independent of pluviometric precipitation, sulfentrazone has low soil mobility, thus remaining in the surface layer (Bachega *et al*., 2009). The herbicide sulfentrazone is more active in soils with a more clayey texture, or which contain high levels of organic material in relation to other types (Reddy and Locke, 1998), and is sorbed with great efficiency and desorbed slowly (Dan *et al*., 2011). Thus, with sulfentrazone absorbed from the soil solution by plant roots, the occurrence of rains and degradation of its molecule by microorganisms may propitiate continuous availability of its molecule in the soil, thus possibly causing high phytotoxicity in crops over time, especially for those that are more susceptible to this herbicide, as is the case with the Nidera 5909 RG cultivar (Table 3). For the two soy cultivars, at 14 DAE, all of the herbicides, with the exception of sulfentrazone, caused on average 5% phytotoxicity (Table 3). At 21 DAE the application of the herbicides s-metolachlor and metribuzin caused reduced symptoms of phytotoxicity in the plants from the two cultivars, with only metribuzin differing from the control samples in the Coodetec STS 249 RR cultivar. The greatest *Raphanus* spp. controls at 14 DAE were obtained with the application of diclosulan and metribuzin (Table 4). At 28 DAE, only diclosulan provided satisfactory control of this weed (above 90%), not differing from the clean sample. According to Oliveira Jr. *et al*. (2002), the application of diclosulan in 30 g ha^{-1} doses causes *Raphanus raphanistrum* control close to 100%, 42 days after the its application. Diclosulan acts as an inhibitor of the acetolactate synthase enzyme (ALS), which is responsible for catalyzing condensation of the two pyruvate molecules, forming an acetolactate molecule, as well as allowing for condensation of one piruvate molecule with one acetobutirate molecule, and forming acetohydroxibutirate (Roman *et al*., 2007).

Table 4. Control of *Raphanus* spp. at 14 (C_{14}) and 28 (C_{28}) DAE, *Ipomoea* spp. at 28 DAE (C_{28}) and *Bidens* spp. at 14 DAE (C_{14}) as affected by application of different herbicides in pre-emergency

Treatment	*Raphanus* spp. (%)		*Ipomoea* spp. (%)	*Bidens* spp. (%)
	C_{14} DAE[1]	C_{28} DAE	C_{28} DAE	C_{14} DAE
Control (clean)	100.0 a[2]	100.0 a	100.0 a	100.0 a
Control (infested)	0.0 d	0.0 c	0.0 d	0.0 c
S-metolachlor	38.5 c	13.3 c	15.7 c	45.2 b
Diclosulan	98.8 a	99.0 a	98.5 a	98.8 a
Metribuzin	94.9 ab	45.0 b	45.1 b	96.5 a
Sulfentrazone	88.4 b	47.0 b	98.9 a	98.1 a
C.V. (%)	12.88	32.25	14.62	11.69

[1]Days after emergency of soybean plants; [2]Means followed by same letter in the column do not differ statistically by Duncan's test ($p \leq 0.05$).

With inhibition of the ALS, a reduction occurs in the quantity of the side chain amino acids valine, isoleucine, and leucine, inhibition of cellular division, accumulation of acetrohydroxibutirate, and reduction in translocation of photoassimilates in the phloem (Roman *et al*., 2007).

Moreover, inhibition of the ALS interrupts proteic synthesis, subsequently affecting the formation of desoxyribosenucleic acid (DNA) (Vitorino, 2011). In the evaluation of the *Ipomoea* spp. control at 28 DAE, the use of sulfentrazone, as well as diclosulan, caused the best controls of this weed, in which these did not differ from the clean sample (Table 4). Papers written on the application of sulfentrazone demonstrate *Ipomoea* spp. control between 90 and 100%, in evaluation periods that vary from 15 to 120 DAA (Campos *et al*., 2009; Azania *et al*., 2009). The application of the diclosulan herbicide also provided increased *Ipomoea grandifolia* control (Carbonari *et al*., 2008), supporting the results found in this study. Out of all of the herbicides evaluated, s-metolachlor was the one which controlled *Raphanus* spp. with the least efficiency at 14 and 28 DAE, as well as *Ipomoea* spp. at 28 DAE and *Bidens* spp. at 14 DAE. In the two cultivars studied, the greatest *Bidens* spp. control at 28 DAE was verified with the application of the herbicides diclosulan and sulfentrazone, in which these did not differ from the clean sample (Table 5). The application of diclosulan in 25 g i.a ha^{-1}doses provided 99% control of the *Bidens pilosa* plants 28 days after application (Lopes-Ovejero *et al*., 2013). The application of sulfentrazone in 0.5 Kg i.a ha^{-1} doses provided 100% control of the *Bidens pilosa* and *Bidens subalternans* biotypes that are resistant to ALS, at 28 DAA (Nicolai *et al*., 2006). Among the herbicides evaluated, s-metolachlor caused less *Bidens* spp. control at 28 DAE in the two cultivars (Table 5). The low *Bidens* spp. control percentage resulting from the application of s-metolachlor is due to the fact that this herbicide exerts little or no control over dicotyledons (Silva and Silva, 2007). The Nidera 5909 RG cultivar experienced a reduction in productivity with all of the treatments evaluated, compared to the clean sample (Table 5). For this same cultivar, the herbicide sulfentrazone caused a greater reduction in productivity compared to the other herbicides tested, with a reduction after applying this herbicide of approximately 33% when compared to the weeded sample. As well as the phytotoxicity caused by the herbicide sulfentrazone, it should be highlighted that of the three weeds evaluated, this herbicide controlled only *Ipomoea* spp. satisfactorily (Table 4). Thus, the low control indices for the species *Raphanus* spp. and *Bidens* spp. also possibly contributed to the reduction in productivity of the Nidera 5909 RG cultivar.

Table 5. Control of *Bidens* spp. at 28 DAE ($C_{Bidens28}$), and grain productivity (productivity) in soybean cultivars Nidera 5909 RG (NA) and Coodetec STS 249 RR (CD), as affected by application of different herbicides in pre-emergency

Treatment	$C_{Bidens28}$ (%)		Productivity (Kg ha^{-1})	
	NA	CD	NA	CD
Control (clean)	100.0 a^{ns1}	100.0 a	4228 a*	3805 a
Control(infested)	0.0 d^{ns}	0.0 d	2718 b*	1998 c
S-metolachlor	18.5 c^{ns}	14.3 c	3459 b^{ns}	2723 b
Diclosulan	99.0 a^{ns}	99.0 a	3192 b^{ns}	3352 a
Metribuzin	75.0 b*	46.8 b	2708 b^{ns}	2725 b
Sulfentrazone	98.3 a^{ns}	92.7 a	1380 c*	3495 a
C.V (%)	8.77	12.86	15.91	10.50

[1]Means followed by same letter, in the column, compare herbicides inside of cultivar by Duncan's test ($p \leq 0.05$), and * (significative) or ^{ns} (non significative) in the line compare cultivars effect inside of herbicides factor by t test ($p \leq 0.05$).

In the Coodetec STS 249 RR cultivar, the productivity achieved with the use of the herbicides diclosulan and sulfentrazone did not differ from the clean sample (Table 5). The interference caused by weeds (infested sample) to the Coodetec STS 249 RR cultivar resulted in a reduction in productivity of more than 47%, compared with the clean sample, with this being the one that caused the greatest reduction in this cultivar's productivity, out of all of the treatments evaluated. For the treatments with the application of the herbicides s-metolachlor and metribuzin, an average reduction of 28% was observed in the productivity of the Coodetec STS 249 RR cultivar, in relation to its respective clean sample, which may be due to the reduced weed control caused by these molecules (Tables 4 and 5). It is known that the occurrence of weeds in the areas reduces the formation of trefoils and dry material from the cultivated plants, with high invader population densities affecting the number of pods per plant, grain mass, and crop productivity, and these variables are affected in accordance with the time the crop has co-existed with weeds (Pittelkow *et al*., 2009). The Nidera 5909 RG cultivar was more productive than Coodetec STS 249 RR in both the clean and the infested samples, which demonstrates the greater productive potential of the first cultivar (Table 5). It was observed that when the same weed population interference is experienced (infested sample), the Nidera 5909 RG cultivar was 26% more productive in relation to the Coodetec STS 249 RR cultivar. When the herbicides s-metolachlor, diclosulan, and metribuzin were applied, there was no difference in productivity between the tested cultivars. The application of the herbicide sulfentrazone reduced the productivity of the Nidera 5909 RG cultivar by more than 60% in relation to the Coodetec STS 249 RR cultivar. The greater reduction in the productivity of the Nidera 5909 RG cultivar, due to the application of sulfentrazone, possibly occurred as a result of the reduction in the photosynthetic apparatus in important stages of development for the plants, with an expansion and formation of pods and the beginning of seed development (Arruda *et al*., 1999) possibly being related with the increased degree of phytotoxicity caused by this herbicide to this cultivar (Table 3). Aiming to identify morphological characteristics in soy plants that provide greater competitive ability to them, when faced with competing plants, it was verified that the soy plants that present more dry material in the stem at 45 DAE, and more dry material in the aerial part at 60 DAE, have a greater competitive ability in relation to forage turnips (Bianchi *et al*., 2011). These same authors also observed that the height of the plants, as well as the number and length of branches provide soy plants with greater competitive ability against weeds. Thus, the higher productivity observed in the Nidera 5909 RG cultivar compared with Coodetec STS 249 RR, when these are in competition with weeds (infested sample), is possibly due to the fact the former presents genetic characteristics that provide it with greater competitive ability in relation to the latter, when suffering from weed interference. For the experiment with post-emergent herbicides, interaction was verified between the factors for the phytotoxicity variable at 7, 14, and 21 DAA. For grain productivity, *Raphanus* spp., *Bidens* spp., and *Ipomoea* spp. control at 14 and 28 DAA, an isolated effect of the herbicides was verified. The highest phytotoxicity percentages were observed from the application of carfentrazone ethyl in both cultivars, at 7, 14, and 21 DAA, compared to the other treatments (Table 6). The application of carfentrazone ethyl in soy caused amore than 26% reduction in plant foliar area (Roman *et al*., 2005).

The second highest phytotoxicity observed resulted from the application of chlorimuron ethyl in both cultivars, at 7 DAA, and only in the Nidera 5909 RG cultivar at 14 and 21 DAA (Table 6). For the Coodetec STS 249 RR cultivar at 14 and 21 DAA, after carfentrazone ethyl, the greatest phytotoxicity symptoms were caused by the application of the herbicide imazethapyr, with the symptoms observed for this at 21 DAA not differing from the control sample values. Evaluating the selectivity of different post-emergent herbicides over soy cultivation, it was verified that the application of chlorimuron ethyl caused 12.5% phytotoxicity in plants in the initial stage of crop development, with this value reducing with crop development (Correia *et al*., 2008). Also, the application of imazethapyr in 100 g i.a ha^{-1} doses caused 17% phytotoxicity at 3 DAA, and at 14 DAA the phytotoxicity caused by this is similar to that observed in the control samples without application (Correia *et al*., 2008). The application of chlorimuron ethyl caused greater phytotoxicity in the Nidera 5909 RG cultivar when compared to Coodetec STS 249 RR in the evaluations carried out, at 7 and 14 DAA (Table 6). The Coodetec STS 249 RR cultivar is tolerant to the chemical group of sulphonylureas (Coodetec, 2015) which the herbicide chlorimuron ethyl belongs to, and thus presents greater selectivity to this in relation to the Nidera 5909 RG cultivar. The highest *Raphanus* spp. control percentages at 14 and 28 DAA were verified where chlorimuron ethyl, as well as imazethapyr, was applied, in which the control caused by these did not differ from that verified in the clean sample (Table 7). All of the herbicides, with the exception of carfentrazone ethyl, caused increased *Bidens* spp. control at 14 and 28 DAA. The highest level of *Ipomoea* spp. control at 14 and 28 DAA was observed when carfentrazone ethyl as applied.

Out of all of the herbicides used, carfentrazone ethyl resulted in the lowest *Raphanus* spp. and *Bidens* spp. control percentage, in both evaluations. In aiming to find alternatives for the control of *Raphanus raphanistrum* resistant to the herbicide metsulfuron methyl, it was verified that the application of chlorimuron ethyl caused a high control percentage for the species susceptible to this herbicide (Costa and Rizzardi, 2013). The application of chlorimuron ethyl in 50 g i.a ha^{-1} doses provided control of *Bidens pilosa* and *Bidens subalternans*, which are susceptible to ALS, close to 100% (Lopes-Ovejero *et al*., 2006). Also, in evaluating weed control with different herbicides, it was verified that the application of carfentrazone ethyl in 30 g i.a ha^{-1} doses provided 100% *Ipomoea grandifolia* control at 7 DAA, and 97% at 14 DAA (Monquero *et al*., 2001).

With the exception of chlorimuron ethyl and imazethapyr, all of the other herbicides, as well as the infested sample, negatively affected soy productivity, with the most damaging effects observed being when the herbicide carfentrazone ethyl was applied and in the infested sample (Table 7). The application of carfentrazone ethyl reduced soy plant productivity by around 61%, when compared to the clean sample, and 34% in relation to the infested sample. Soy cultivation with weed interference (infested sample) caused a 40% reduction in productivity in the plants of this species, compared to the clean sample. It can thus be verified that both the application of herbicides with an increased negative effect such as carfentrazone ethyl, as well as intense competition with different weeds, can cause losses in soy productivity, leaving it up to producers and technicians to correctly choose the form of management adopted in order for the crop to achieve its full productive potential.

Table 6. Phytotoxicity of soybean cultivars Nidera 5909 RG (NA) and Coodetec STS 249 RR (CD) at 7 ($P_{7\,DAA}$); 14 ($P_{14\,DAA}$)e 21 ($P_{21\,DAA}$) days after application of different herbicides in post emergency

Treatment	Phytotoxicity (%)					
	$P_{7\,DAA}$[1]		$P_{14\,DAA}$		$P_{21\,DAA}$	
	NA	CD	NA	CD	NA	CD
Control (clean)	0.0 c^{ns}[2]	0.0 d	0.0 d^{ns}	0.0 c	0.0 d^{ns}	0.0 b
Control (infested)	0.0 c^{ns}	0.0 d	0.0 d^{ns}	0.0 c	0.0 d^{ns}	0.0 b
Chlorimuron-ethyl	30.5 b*	16.0 b	23.5 b*	10.0 bc	8.0 b^{ns}	5.5 b
Imazethapyr	9.5 c^{ns}	8.5 c	4.3 cd^{ns}	13.3 b	3.5 c^{ns}	7.8 b
Bentazon	6.0 c^{ns}	5.5 cd	8.8 c^{ns}	6.8 bc	5.3 bc^{ns}	4.0 b
Carfentrazone ethyl	56.3 a^{ns}	53.8 a	54.0 a^{ns}	58.5 a	46.3 a*	58.5 a
C.V. (%)	35.76	24.60	23.82	42.71	18.57	41.01

¹Days after application; ²Means followed by same letter, in the column, compare herbicides inside of cultivar by Duncan's test ($p \leq 0.05$), and * (significative) or ^{ns} (non significative) in the line compare cultivars effect inside of herbicides factor by t test ($p \leq 0.05$).

Table 7. Control of *Raphanus* spp., *Bidens* spp. and *Ipomoea* spp. at 14 (C_{14}) and 28 DAA (C_{28}), and soybean grain productivity (Produc) days after application of different herbicides in post emergency

Treatment	*Raphanus* spp. (%)		*Bidens* spp. (%)		*Ipomoea* spp. (%)		Produc (Kg ha^{-1})
	14 DAA[1]	28 DAA	14 DAA	28 DAA	14 DAA	28 DAA	
Control (clean)	100.0 a[2]	100.0 a	100.0 a	100.0 a	100.0 a	100.0 a	3852 a
Control (infested)	0.0 d	0.0 d	0.0 c	0.0 c	0.0 d	0.0 d	2295 c
Chlorimuron-ethyl	99.1 a	99.1 a	97.5 a	99.0 a	87.5 b	96.1 ab	3447 ab
Imazethapyr	99.1 a	99.1 a	96.6 a	97.6 a	68.4 c	91.0 bc	3878 a
Bentazon	78.9 b	94.3 b	96.6 a	96.4 a	80.1 b	87.3 c	3204 b
Carfentrazone-ethyl	22.5 c	5.7 c	32.3 b	8.1 b	98.5 a	96.1 ab	1519 d
C.V (%)	9.07	5.48	7.64	5.23	14.04	9.68	15.91

¹Days after application; ² Means followed by same letter in the column do not differ statistically by Duncan's test ($p \leq 0.05$).

Conclusion

Out of the herbicides applied in pre-emergence, sulfentrazone causes the greatest phytotoxicity in both of the cultivars studied, while in post-emergence, carfentrazone ethyl causes the greatest symptoms of phytotoxicity. In pre-emergence, the greatest *Raphanus* spp. and *Bidens* spp. controls are obtained with the application of the herbicides diclosulan and metribuzin, and the use of sulfentrazone and diclosulan provides the greatest *Ipomoea* spp. controls. With the exception of carfentrazone ethyl, all of the herbicides used in post-emergence efficiently control *Raphanus* spp. and *Bidens* spp., and the application of chlorimuron ethyl, imazethapyr, and carfentrazone also controls *Ipomoea* spp. The herbicide sulfentrazone, when applied in pre-emergence, reduces the productivity of the Nidera 5909 RG cultivar, while carfentrazone, when applied in post-emergence, reduces the productivity of both cultivars, compared with the infested sample.

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