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ORIGINAL ARTICLE

Selectivity of nicosulfuron isolated or in tank mixture to glyphosate and sulfonylurea tolerant soybean

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Abstract

The aim of the present work was to evaluate the selectivity of nicosulfuron, alone and in combinations, applied in post-emergence (V4) of glyphosate and sulfonylurea tolerant (RR/STS) soybean. The experiments were conducted in 2015/16 and 2016/17, in Piracicaba – state of São Paulo (SP). In 2016/17, the experiment was also conducted in Palotina – state of Paraná (PR). The experiment was a randomized block design, with four repetitions and 16 treatments, with combinations of nicosulfuron, glyphosate, chlorimuron, sulfometuron and cloransulam, applied alone or in tank mixture. Crop injury and variables related to agronomic performance were evaluated. Data were subjected to analysis of variance and treatment means were compared by the Tukey test. The results obtained are significant in the positioning of herbicides in RR/STS soybean, since in the five experiments, all the treatments were selective, except for glyphosate + sulfometuron which reduced the yield of a cultivar (CD 2630 RR/STS) in the 2015/16 season.

Key words: ALS inhibitors, chlorimuron, cloransulam, *Glycine max,* glyphosate, herbicide-tolerant crops, nicosulfuron, sulfometuron, tank mixture

Introduction

The area occupied by soybean crop in Brazil, in the 2017/18 season reached 35.02 million hectares (Companhia Nacional de Abastecimento – CONAB 2018), of which 96% were transgenic crops, tolerant to herbicides or resistant to insects, or both (Céleres 2018).

Sulfonylurea-tolerant soybean (STS®) was developed by the technique of seed mutagenesis using the alkylating agent ethylmethanesulfonate (EMS), which is not a transgenic crop. The EMS agent does not cause mutation by insertion into the DNA, but by modifying the already present base, introducing an alkyl radical (Rogozin *et al*. 2001). Mutant grains of 'Williams 82' soybean cultivar were selected according to tolerance to chlorsulfuron sulfonylurea. After the breeding process, the cultivar W20 was developed, which presented high tolerance, in post- and pre-emergence, for some sulfonylureas (Walter *et al*. 2014).

Tolerance to sulfonylureas in STS cultivars is determined by two semi-dominant alleles, designated Als1 and Als2 (Ghio *et al*. 2013; Walter *et al*. 2014). The Als1 allele confers tolerance to herbicides chlorimuron, nicosulfuron, rimsulfuron, sulfometuron, thifensulfuron, tribenuron and flucarbazone. The Als2 allele confers tolerance to these same herbicides as well as to imazapyr (Walter *et al*. 2014). STS cultivars are highly tolerant to the herbicide chlorimuron (Green 2007), which can be applied up to four times the maximum recommended rate for non-STS cultivars (Roso and Vidal 2011).

The herbicide glyphosate is very important in the management of weeds, especially in soybean and maize crops (Bentivegna *et al.* 2017). However, the association and rotation of herbicides are important tools in the management of weeds which are difficult to control (Riar *et al.* 2013).

Studies report tolerance of STS cultivars to chorimuron, prosulfuron, thifensulfuron, nicosulfuron, metsulfuron and other herbicides (Nolte and Young 2002; Anderson and Simmons 2004; Poston *et al.* 2008; Silva *et al.* 2016; Albrecht *et al.* 2017). However, little information is available on possible mixtures of these, and other herbicides.

Sulfonylureas have the inhibiting mechanism of the acetolactate synthase (ALS) enzyme. The ALS inhibitors control mainly dicotyledonous weeds. Susceptible plants become chlorotic, wither and die 7 to 14 days after treatment. They are widely used for weed control in wheat, rice, soybean, barley, cotton, potato and maize (Durner *et al.* 1991). However, it is important to highlight the risks of selection of weed biotypes resistant to these herbicides. The group of ALS inhibitors has 160 distinct species with cases of resistance (Heap 2018). Thus, the rotation of herbicide action mechanisms is fundamental in the prevention of resistance.

It is believed that nicosulfuron and other ALS inhibitors, alone and in tank mixture, are selective for STS soybean. Thus, the aim of the present work was to evaluate the selectivity of nicosulfuron and other herbicides, alone and in tank mixture, applied in post-emergence (V4) of glyphosate and sulfonylurea tolerant (RR/STS) soybean.

Materials and Methods

The experiments were conducted in 2015/16 and 2016/17, in Piracicaba – state of São Paulo (SP). In 2016/17, the experiment was also conducted in Palotina – state of Paraná (PR). In 2015/16, the cultivars CD 2630 RR/STS and BMX Turbo RR/STS were used in experiments I and II, respectively. In 2016/17 in Piracicaba, cultivars DM 61I59 RR2/STS (experiment III) and BMX Garra RR2/STS (experiment IV), in Palotina, the cultivar BMX Garra RR2/STS (experiment V). All cultivars present an indeterminate growth habit.

The climate of the region of Piracicaba is characterized as Cwa by the climatic classification of Köppen, that is, subtropical humid with drought in the winter. While the climate of the Palotina region is Cfa – subtropical humid mesothermal, with a predominance of hot summers, low frequency of severe frosts and a tendency to a concentration of rainfall in the summer. The distribution of rainfall and temperature during each experiment is shown below (Fig. 1).

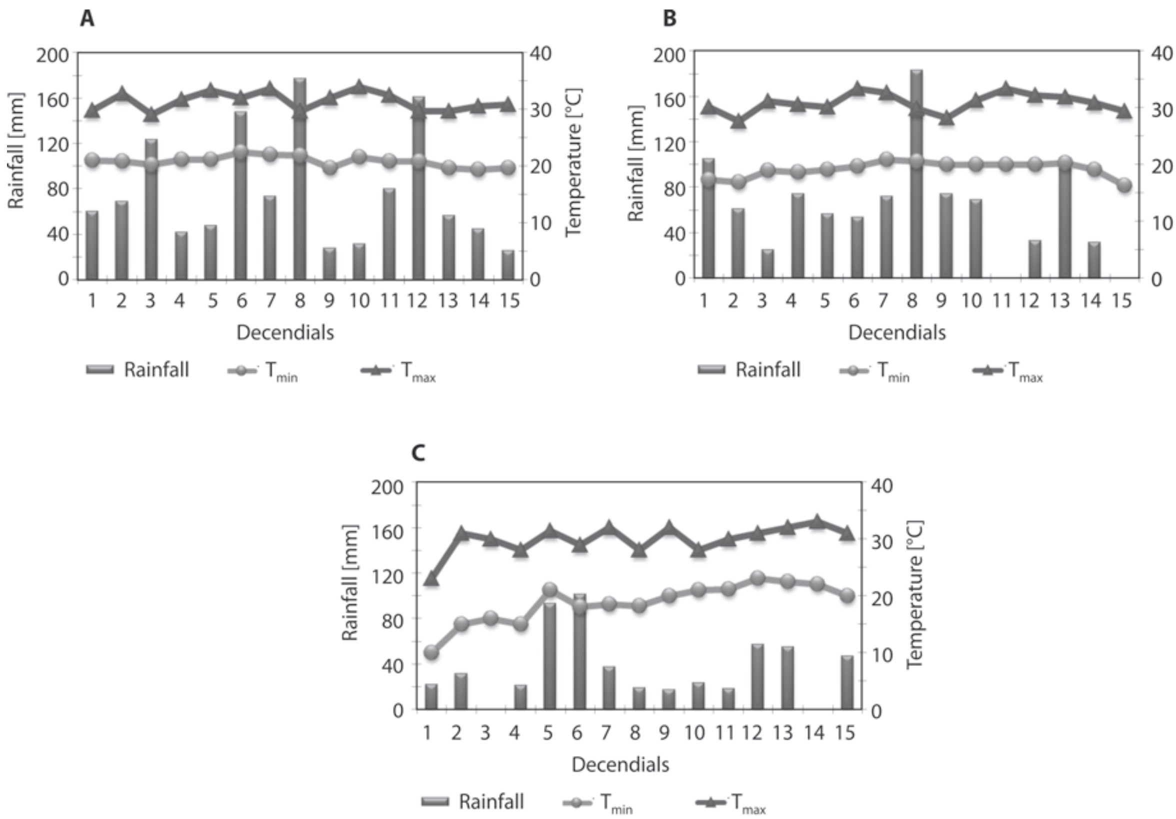

Fig. 1. Rainfall, minimum and maximum average temperature for the period referring to the soybean crop cycle: A – season 2015/16, Piracicaba – state of São Paulo; B – season 2016/17, Piracicaba – state of São Paulo; C – season 2016/17, Palotina – state of Paraná

Fertilization practices, crop implementation and phytosanitary management were carried out in accordance with Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA) recommendations (EMBRAPA 2013). All the plots were kept free of weed interference by manual weeding. The physical and chemical analysis of the soil, from the experimental areas is shown below (Table 1).

The experimental design was a randomized complete block design, with four repetitions and 16 treatments (Table 2). The experimental units consisted of five-m-long plots with six soybean rows, spaced 45 cm apart, and the four central rows were considered the experimental area, disregarding the first and last meter of each plot. Treatments were applied at the V4 developmental stage of soybean plants, via a CO_2 pressurized backpack sprayer equipped with a bar and four spray nozzles at a constant pressure of 2 bar, providing a spray volume of 200 $l \cdot ha^{-1}$ at speed of 1 $m \cdot s^{-1}$, and the ends were positioned at a height of 50 cm from the target.

Crop injury was evaluated 7, 14, 21 and 28 days after application (DAA), through visual evaluations, in which percentages ranged from 0 to 100% for each experimental unit (where 0 represents no injuries, and 100% – death of the plants) (Velini *et al.* 1995).

The variables related to agronomic performance (plant height, number of pods per plant, yield, and weight of 1,000 grains) were also assessed. The height assessment was carried out when the plants reached the R7 stage. For the determination of this variable, ten plants, randomly chosen in the experimental area of the plots, were evaluated using a wooden ruler, with the results expressed in centimeters. The number of pods per plant was evaluated at full maturity (R8 stage) by manually counting the number of pods in ten plants randomly chosen in the experimental area of each plot.

Table 2. Treatments consisting of the application of herbicides on RR/STS soybean

Treatments	Rates*
Control	–
Glyphosate	960
Nicosulfuron	60
Chlorimuron	20
Sulfometuron	7.5
Cloransulam	40
Glyphosate + nicosulfuron	960 + 60
Glyphosate + chlorimuron	960 + 20
Glyphosate + sulfometuron	960 + 7.5
Glyphosate + cloransulam	960 + 40
Glyphosate + nicosulfuron + chlorimuron	960 + 60 + 20
Glyphosate + chlorimuron + sulfometuron	960 + 20 + 7.5
Glyphosate + chlorimuron + cloransulam	960 + 20 + 7.5
Nicosulfuron + chlorimuron	60 + 20
Chlorimuron + sulfometuron	20 + 7.5
Chlorimuron + cloransulam	20 + 40

*rates at grams of acid equivalent per hectare [g a.e. $\cdot$ ha^{-1}] for the herbicide glyphosate; for other herbicides rates at grams of active ingredient per hectare [g a.i. $\cdot$ ha^{-1}]

Plants were harvested from the three central rows, disregarding the first and last meter of the plot, totaling a harvested area of 4.05 m^2. The grains produced in each plot had their mass measured and the moisture corrected to 13% to calculate the yield. For the 1,000 grain weight, the weight of two sub-samples of 100 grains per plot was measured, the values were multiplied by ten and the moisture corrected to 13%.

Table 1. Results of soil chemical and physical analysis of the experimental area, at depths from 0 to 20 cm

Piracicaba – state of São Paulo									
pH ($CaCl_2$)	Al	H + Al	P (resin)	K	Ca	Mg	SB	CEC	V
5.3	< 1.0	25.0	10.0	2.8	26.0	13	41.8	66.8	63.0
	clay			silt			sand		
	41.0			5.0			54.0		
Palotina – state of Paraná									
pH ($CaCl_2$)	Al	H + Al	P (mehlich)	K	Ca	Mg	SB	CEC	V
5.6	< 1.0	46.1	19.4	2.2	55.1	14.7	72.0	118.1	61.0
	clay			silt			sand		
	66.3			18.7			15.0		

Al, H + Al, K, Ca, Mg, SB – sum of bases; CEC – cation exchange capacity [$mmol_c \cdot dm^{-3}$]; P [$mg \cdot dm^{-3}$], V – base saturation, clay, silt and sand [%]

Statistical analysis

Data were tested by analysis of variance (ANOVA). And the means of the treatments were compared by the Tukey's test ($p > 0.05$), according to Pimentel-Gomes and Garcia (2002).

Results

Symptoms of injury were found for experiments I, II, IV and V, mainly in those with applications of herbicide combinations. In experiment III, no differences were detected between treatments for any of the four evaluations (Table 3–5). If present the symptoms were characterized by leaf chlorides and little purple spots. It is important to highlight that for the five experiments, for the applications of glyphosate (960 g a.e. · ha^{-1}) and nicosulfuron (60 g a.i. · ha^{-1}), the crop injury scores did not differ from the control scores without application.

Results for variables related to the agronomic performance of experiments I and II are listed in Table 6. In experiment I, there was a reduction in the yield of soybean plants under application of glyphosate + sulfometuron (7.5 g a.i. · ha^{-1}) only in relation to the control without application. For the 1,000 grain weight, some differences were observed between treatments, however none of the treatments differed from the control. For the other variables, in experiments I and II, no differences were detected for application of the herbicides in post-emergence of the RR/STS soybean.

Similarly, no differences were observed between the treatments for the variables related to agronomic performance in experiments III and IV (Table 7). With the exception of plant height (in experiment III some differences were verified) no treatment reduced height in comparison with the control.

Reduction in plant height was observed in experiment V, for application of sulfometuron, alone and in combinations with glyphosate or glyphosate + chlorimuron (60 g a.i. · ha^{-1}) (Table 8). Some differences were also observed for the number of pods per plant, however no treatment differed from the control. There were no differences between treatments for the other variables in experiment V.

Discussion

Silva *et al.* (2016) reported no significant crop injury or reduction in agronomic performance variables in the soybean cultivar CD 2630 RR/STS for post-emergence

Table 3. Crop injury [%], at 7, 14, 21 and 28 days after application (DAA), of RR/STS soybean plants under application of herbicides used (experiments I and II)

Treatments	Experiment I (days after application)				Experiment II (days after application)			
	7	14	21	28	7	14	21	28
Control	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a
Glyphosate	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a
Nicosulfuron	11.2 abc	6.5 abc	2.5 a	3.7 ab	7.5 abc	8.7 ab	5.0 a	3.2 ab
Chlorimuron	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a
Sulfometuron	16.2 c	26.2 cd	21.2 b	10.0 ab	21.2 d	32.5 d	28.7 b	18.7 c
Cloransulam	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a
Glyphosate + nicosulfuron	21.2 c	21.2 bcd	15.0 ab	5.0 ab	17.5 cd	23.8 cd	20.0 ab	8.7 abc
Glyphosate + chlorimuron	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a
Glyphosate + sulfometuron	20.0 c	28.7 d	22.5 b	10.0 ab	23.8 d	32.5 d	27.5 b	16.2 bc
Glyphosate + cloransulam	1.2 ab	1.2 ab	1.2 a	1.2 a	0.0 a	0.0 a	0.0 a	0.0 a
Glyphosate + nicosulfuron + chlorimuron	21.2 c	21.2 bcd	12.5 ab	3.7 ab	11.2 abcd	8.7 ab	10.0 ab	5.0 abc
Glyphosate + chlorimuron + sulfometuron	15.0 bc	20.0 abcd	11.2 ab	3.7 ab	22.5 d	23.8 cd	12.5 ab	0.0 a
Glyphosate + chlorimuron + cloransulam	0.75 ab	0.0 a	0.0 a	0.0 a	2.5 ab	2.5 ab	1.2 a	0.0 a
Nicosulfuron + chlorimuron	17.5 c	13.7 abcd	8.7 ab	2.5 ab	13.7 bcd	13.7 bcd	5.0 a	2.5 ab
Chlorimuron + sulfometuron	17.5 c	28.7 d	22.5 b	12.5 b	7.5 abc	8.8 a	6.2 a	2.5 ab
Chlorimuron + cloransulam	0.0 a	1.2 ab	1.2 a	1.2 a	0.7 ab	0.0 a	0.0 a	0.0 a
Mean	8.9	10.6	7.4	3.3	8.0	9.9	7.3	3.7
MSD	14.7	20.7	15.7	11.0	13.5	22.7	20.5	14.5
C.V. [%]	32.4	40.7	39.2	49.7	29.7	39.0	41.7	50.5

Means followed by different letters, in the same column, are significantly different by Tukey's test at 5% probability, C.V. – coefficient of variation

Table 4. Crop injury [%], at 7, 14, 21 and 28 days after application (DAA), of RR/STS soybean plants under application of herbicides used (experiments III and IV)

Treatments	Experiment III (days after application)				Experiment IV (days after application)			
	7	14	21	28	7	14	21	28
Control	0.0^{ns}	0.0^{ns}	0.0^{ns}	0.0^{ns}	0.0 a	0.0 a	0.0 a	0.0^{ns}
Glyphosate	0.0	0.0	0.0	0.0	0.0 a	0.0 a	0.0 a	0.0
Nicosulfuron	3.8	2.5	2.0	0.0	3.8 a	3.3 ab	2.0 ab	2.0
Chlorimuron	0.0	0.0	0.0	0.0	1.3 a	0.0 a	0.0 a	0.0
Sulfometuron	2.5	1.3	1.3	1.3	1.3 a	0.8 a	0.8 a	0.0
Cloransulam	1.3	1.3	1.3	1.3	0.0 a	0.0 a	0.0 a	0.0
Glyphosate + nicosulfuron	10.0	8.8	5.8	3.8	12.5 bc	8.0 ab	2.8 ab	0.0
Glyphosate + chlorimuron	0.0	0.0	0.0	0.0	0.0 a	0.0 a	0.0 a	0.0
Glyphosate + sulfometuron	3.8	4.3	2.0	1.3	3.8 a	3.8 ab	3.3 ab	1.3
Glyphosate + cloransulam	2.5	1.3	1.3	1.3	1.3 a	1.3 a	0.0 a	0.0
Glyphosate + nicosulfuron + chlorimuron	8.8	7.5	5.0	3.8	13.8 c	12.5 b	8.8 b	4.3
Glyphosate + chlorimuron + sulfometuron	8.8	7.5	4.0	2.8	7.5 abc	7.8 ab	3.8 ab	2.5
Glyphosate + chlorimuron + cloransulam	2.5	0.0	0.0	0.0	0.0 a	0.0 a	0.0 a	0.0
Nicosulfuron + chlorimuron	5.0	4.3	3.3	1.3	5.0 ab	4.5 ab	2.5 ab	1.3
Chlorimuron + sulfometuron	3.3	3.3	2.0	0.8	2.5 a	1.3 a	1.3 a	1.3
Chlorimuron + cloransulam	2.0	0.0	0.0	0.0	1.3 a	1.3 a	1.3 a	0.0
Mean	3.4	2.6	1.7	1.1	3.4	2.8	1.6	0.8
MSD	11.6	10.9	7.7	7.4	8.7	9.7	7.3	5.1
C.V. [%]	50.5	50.9	45.3	49.6	37.7	40.8	42.5	42.5

Means followed by different letters, in the same column, are significantly different by Tukey's test at 5% probability.
^{ns}non-significant values do not differ at 5% probability, C.V. – coefficient of variation

Table 5. Crop injury [%], at 7, 14, 21 and 28 days after application (DAA), of RR/STS soybean plants under application of herbicides used (experiment V)

Treatments	Days after application			
	7	14	21	28
Control	0.0 a	0.0 a	0.0 a	0.0 a
Glyphosate	2.3 ab	2.8 ab	0.5 a	0.3 a
Nicosulfuron	3.8 ab	3.0 ab	2.0 a	0.5 a
Chlorimuron	5.3 ab	5.5 bcd	1.3 a	0.3 a
Sulfometuron	13.8 e	10.5 ef	7.3 b	3.5 bc
Cloransulam	6.0 b	5.3 bcd	0.5 a	0.5 a
Glyphosate + nicosulfuron	6.8 bc	5.0 bcd	1.3 a	1.0 a
Glyphosate + chlorimuron	5.8 ab	5.0 bcd	2.8 a	1.3 ab
Glyphosate + sulfometuron	22.5 f	17.5 g	12.5 c	6.3 d
Glyphosate + cloransulam	6.5 b	7.5 cde	2.3 a	1.0 a
Glyphosate + nicosulfuron + chlorimuron	14.0 e	7.8 cde	3.0 a	1.8 ab
Glyphosate + chlorimuron + sulfometuron	17.5 ef	13.8 fg	7.3 b	5.0 cd
Glyphosate + chlorimuron + cloransulam	13.0 de	8.3 de	1.3 a	1.3 ab
Nicosulfuron + chlorimuron	13.8 e	5.8 bcd	2.0 a	1.3 ab
Chlorimuron + sulfometuron	12.5 cde	10.8 ef	2.8 a	0.8 a
Chlorimuron + cloransulam	7.3 bcd	3.5 abc	0.5 a	0.3 a
Mean	9.4	7.0	2.9	1.5
MSD	5.8	4.4	3.3	2.4
C.V. [%]	10.2	11.3	15.0	16.6

Means followed by different letters, in the same column, are significantly different by Tukey's test at 5% probability, C.V. – coefficient of variation

Table 6. Variables related to agronomic performance of RR/STS soybean plants under application of herbicides used (experiments I and II)

Treatments	Experiment I				Experiment II			
	H	NPP	WG	Y	H	NPP	WG	Y
Control	106.9[ns]	79.3[ns]	110.1 ab	3,722.9 a	75.1[ns]	69.5[ns]	142.1[ns]	3,134.3[ns]
Glyphosate	112.5	78.2	105.6 ab	3,203.0 ab	75.8	76.1	141.0	3,703.0
Nicosulfuron	105.6	71.1	111.2 ab	3,253.6 ab	73.3	72.5	147.7	3,231.4
Chlorimuron	106.1	64.0	109.9 ab	3,168.0 ab	71.3	79.4	144.2	3,614.3
Sulfometuron	96.7	67.8	105.6 ab	2,983.9 ab	67.4	70.3	129.3	2,644.0
Cloransulam	111.7	70.5	108.3 ab	3,213.8 ab	74.5	74.8	137.6	3,445.5
Glyphosate + nicosulfuron	99.1	61.3	106.9 ab	3,179.5 ab	67.5	71.6	140.6	3,290.5
Glyphosate + chlorimuron	109.9	67.1	107.1 ab	3,274.7 ab	75.2	74.1	141.3	3,659.0
Glyphosate + sulfometuron	100.1	63.8	108.1 ab	2,603.6 b	66.1	72.4	133.3	3,233.2
Glyphosate + cloransulam	106.7	78.2	105.1 b	3,402.0 ab	73.7	75.8	138.0	3,516.6
Glyphosate + nicosulfuron + chlorimuron	99.2	67.2	109.3 ab	2,870.1 ab	68.1	65.7	142.1	2,983.5
Glyphosate + chlorimuron + sulfometuron	105.9	61.7	113.6 a	3,155.9 ab	66.1	66.7	140.3	2,917.2
Glyphosate + chlorimuron + cloransulam	102.9	74.5	109.0 ab	3,350.1 ab	68.8	68.8	144.9	3,460.6
Nicosulfuron + chlorimuron	104.7	70.6	107.9 ab	3,104.7 ab	68.2	69.5	139.6	2,982.9
Chlorimuron + sulfometuron	97.4	66.2	107.1 ab	2,800.1 ab	68.9	76.3	138.7	2,827.9
Chlorimuron + cloransulam	104.5	76.2	107.0 ab	3,302.5 ab	73.4	78.0	145.7	3,481.1
Mean	104.4	69.9	108.2	3,161.7	70.8	72.5	140.4	3,257.8
MSD	17.2	28.4	8.3	1,063.0	10.8	22.2	19.3	1,064.4
C.V. [%]	6.4	15.9	3.0	13.1	5.9	11.9	5.4	12.8

H – plant height [cm], NPP – number of pods · plant^{-1}, WG – weight of 1,000 grains [g], Y – yield [kg · ha^{-1}]; means followed by different letters, in the same column, are significantly different by Tukey's test at 5% probability

[ns] non-significant values do not differ at 5% probability; C.V. – coefficient of variation

(V4) application of glyphosate (960 g a.e. · ha^{-1}), chlorimuron (20 g a.i. · ha^{-1}), cloransulam (40 g a.i. · ha^{-1}) and nicosulfuron (60 g a.i. · ha^{-1}). Likewise, Albrecht *et al.* (2017) reported no significant crop injury or reduction in agronomic performance variables with the cultivar CD 250 RR/STS for the herbicides chlorimuron (up to up to 60 g a.i. · ha^{-1}), metsulfuron (up to 7.2 g a.i. · ha^{-1}) and nicosulfuron (up to 200 g a.i. · ha^{-1}). Results similar to those were verified in the present study.

Similarly, Merotto Júnior et al. (2000) confirmed tolerance to nicosulfuron in CD 201 soybean cultivar, one of the first cultivars with tolerance to sulfonylureas in Brazil. Manley *et al.* (2001) observed crop injury (24 to 45%) in the cultivars W20 STS, Asgrow 9122 STS, Asgrow 3200 STS, Asgrow 4045 STS, with the application of nicosulfuron (35 g a.i. · ha^{-1}) at initial post-emergence, however, no reduction in yield was registered during the four years of cultivation.

Other authors report the selectivity and efficacy of chlorimuron in STS soybean (Nolte and Young 2002; Poston *et al.* 2008). Still, other sulfonylureas are reported to be selective to STS soybean, such as thifensulfuron (Nolte and Young 2002), halosulfuron (Nandula *et al.* 2009), trifloxysulfuron (Porterfield *et al.* 2006) and metsulfuron (Merotto Júnior *et al.* 2000; Albrecht *et al.* 2017). Nevertheless, the latter was not selective for cultivar CD 2630 RR/STS (Silva *et al.* 2016). According to Menendez *et al.* (1994), there are differences in the resistance levels in sulfonylurea-tolerant genotypes. Furthermore, the susceptibility to chlorimuron may vary according to the soybean genotype (Mian *et al.* 1997). Therefore, different STS cultivars may present distinct levels of tolerance to sulfonylureas.

The results obtained in the present work are significant in the positioning of herbicides in RR/STS soybean, since in the five experiments, all the treatments were selective, except for glyphosate + sulfometuron that reduced the yield of a cultivar (CD 2630 RR/STS) in the 2015/16 season. Jeffries *et al.* (2014) verified, at 70 DAA, a reduction of 29% in height and 48% in biomass of soybean cultivar SS5911N R2 (STS), for post-emergence application of sulfometuron (4 g a.i. · ha^{-1}). Piasecki and Rizzardi (2016) observed the efficacy of chlorimuron + sulfometuron in volunteer maize control as well as selectivity of the mixture for the cultivar BMX Turbo RR/STS. Thus, caution is advised in the use of sulfometuron since the selectivity may vary with the cultivar.

The herbicide nicosulfuron, which is non-selective for non-STS soybean cultivars, is registered in Brazil for use only in maize (Rodrigues and Almeida 2011). Even for STS cultivars, there are no clear recommen-

Table 7. Variables related to agronomic performance of RR/STS soybean plants under application of herbicides used (experiments III and IV)

Treatments	Experiment III				Experiment IV			
	H	NPP	WG	Y	H	NPP	WG	Y
Control	98.6 ab*	42.1^{ns}	161.3^{ns}	3,594.0^{ns}	101.6^{ns}	52.8^{ns}	164.5^{ns}	3,339.4^{ns}
Glyphosate	104.1 a	41.6	161.7	3,906.7	105.5	55.8	167.1	3,136.1
Nicosulfuron	95.2 ab	41.2	150.8	3,647.3	99.9	55.2	169.0	3,398.5
Chlorimuron	100.6 ab	39.0	167.0	3,427.0	106.2	54.5	165.2	3,562.2
Sulfometuron	98.0 ab	41.4	159.4	3,382.4	102.8	45.4	166.4	3,535.3
Cloransulam	99.7 ab	39.6	160.7	3,842.6	103.1	55.0	169.9	3,415.9
Glyphosate + nicosulfuron	100.1 ab	40.1	154.4	3,484.6	97.0	56.4	167.0	3,113.0
Glyphosate + chlorimuron	100.4 ab	40.1	161.5	3,614.9	102.6	52.0	167.3	3,133.1
Glyphosate + sulfometuron	89.1 b	41.4	153.0	3,170.1	100.6	45.9	168.2	3,377.6
Glyphosate + cloransulam	100.2 ab	43.6	161.2	3,444.8	105.0	52.3	162.1	3,552.3
Glyphosate + nicosulfuron + chlorimuron	95.0 ab	41.7	150.5	3 748.1	99.0	43.5	170.4	3 392.7
Glyphosate + chlorimuron + sulfometuron	95.2 ab	41.6	152.6	3 244.7	97.3	44.8	162.0	3 349.5
Glyphosate + chlorimuron + cloransulam	101.2 ab	44.2	156.9	3 461.6	103.2	49.6	162.6	3 460.2
Nicosulfuron + chlorimuron	91.9 ab	41.2	151.5	3 323.3	100.0	44.4	168.8	3 297.6
Chlorimuron + sulfometuron	95.6 ab	42.2	157.4	3 823.2	102.9	45.9	161.0	3 510.4
Chlorimuron + cloransulam	98.3 ab	41.1	153.0	3 234.2	102.9	55.9	160.4	3 456.9
Mean	97.7	41.4	157.1	3 521.8	101.8	50.6	165.7	3 376.9
MSD	14.4	11.9	31.2	1 881.6	13.8	20.5	21.8	969.2
C.V. [%]	5.8	11.2	7.7	20.8	5.3	15.8	5.1	11.2

H – plant height [cm], NPP – number of pods · plant^{-1}, WG – weight of 1,000 grains [g], Y – yield [kg · ha^{-1}], C.V. – coefficient of variation
Means followed by different letters, in the same column, are significantly different by Tukey's test at 5% probability.
^{ns} non-significant values do not differ at 5% probability

Table 8. Variables related to agronomic performance of RR/STS soybean plants under application of herbicides used (experiment V)

Treatments	H	NPP	WG	Y
Control	99.2 a	50.5 ab	186.4^{ns}	3,760.0^{ns}
Glyphosate	91.9 abc	47.2 ab	183.9	3,393.2
Nicosulfuron	90.0 abc	46.0 ab	174.2	3,218.2
Chlorimuron	97.8 a	51.8 ab	166.8	3,494.7
Sulfometuron	79.0 bc	66.8 a	183.7	3,356.9
Cloransulam	95.1 ab	55.2 ab	176.0	3,513.3
Glyphosate + nicosulfuron	88.2 abc	44.5 b	184.3	3,278.7
Glyphosate + chlorimuron	95.2 ab	49.7 ab	172.3	3,398.8
Glyphosate + sulfometuron	78.3 bc	50.5 ab	167.5	3,116.7
Glyphosate + cloransulam	89.8 abc	49.4 ab	182.9	3,443.5
Glyphosate + nicosulfuron + chlorimuron	89.0 abc	51.6 ab	188.4	3,432.3
Glyphosate + chlorimuron + sulfometuron	75.9 c	48.9 ab	174.7	3,571.9
Glyphosate + chlorimuron + cloransulam	91.5 abc	47.5 ab	183.8	3,625.0
Nicosulfuron + chlorimuron	97.8 a	45.6 ab	181.1	3,398.8
Chlorimuron + sulfometuron	87.5 abc	49.8 ab	172.1	3 165.2
Chlorimuron + cloransulam	98.3 a	48.6 ab	183.2	3 234.0
Mean	90.3	50.2	178.9	3,400.1
MSD	17.9	22.3	27.6	1,127.1
C.V. [%]	7.7	17.3	6.0	12.9

H – plant height [cm], NPP – number of pods · plant^{-1}, WG – weight of 1,000 grains [g], Y – yield [kg · ha^{-1}]; means followed by different letters, in the same column, are significantly different by Tukey's test at 5% probability;
^{ns} non-significant values do not differ at 5% probability; C.V. – coefficient of variation

dations for the use of this herbicide. In Argentina, where more STS cultivars are available on the market, this technology is used in the management of weeds which are difficult to control, with the possibility of using nicosulfuron and the mixture chlorimuron + sulfometuron (Puricelli *et al.* 2015).

The application of glyphosate + chlorimuron (960 g a.e. · ha^{-1} + 25 g a.i. · ha^{-1}) compromised the agronomic performance of the soybean (non-STS) (Albrecht *et al.* 2012). They showed the risks associated with the use of rates above those recommended for chlorimuron herbicide, in non-STS cultivars. Albrecht *et al.* (2017) reported no significant crop injury or reduction in agronomic performance variables in the soybean cultivar CD 250 RR/STS for post-emergence (V4) application of chlorimuron (up 60 g a.i. · ha^{-1}).

However, even in cultivars STS higher rates of chlorimuron should be recommended with prudence and applied only in specific situations in the management of weeds. The same is true for other ALS inhibitor herbicides, which should be cautiously recommended since we have seen the risks of weed selection resistant to this mechanism of action.

As already highlighted, there is little information on the selectivity of sulfonylureas and other herbicides in soybean STS, especially under cultivation conditions in Brazil. The STS technology has potential use, mainly in the handling of weed eudicotyledons with tolerance or resistance to glyphosate.

Conclusions

In general, soybean cultivars CD 2630 RR/STS, BMX Turbo RR/STS, DM 61I59 RR2/STS and BMX Garra RR2/STS were considered tolerant to post-emergence (V4) application of glyphosate, nicosulfuron, chlorimuron, sulfometuron and cloransulam, isolated or in tank mixture. Only glyphosate (960 g a.e. · ha^{-1}) + sulfometuron (7.5 g a.i. · ha^{-1}) was not selective during one of the seasons for cultivar CD 2630 RR/STS.

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