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The residual effect of metsulfuron on soybean tolerant and non-tolerant to sulfonylureas

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Efecto residual de metsulfurón en soya tolerante y no tolerante a sulfonilureas

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ABSTRACT

Keywords:
Herbicide
Pre-seeding
Safety interval
STS

Metsulfuron is widely used for weed management; however, the residual effect on STS soybean cultivars is unknown. The objective of this work was to evaluate the residual effect of the herbicide metsulfuron on the BMX Garra RR2/STS and M 6410 IPRO (non-STS) soybean cultivars. The herbicide metsulfuron was applied at a rate of 2.4 g a.i. ha^{-1}, in pre-planting of soybean plants. The design was completely randomized in a 2×5 factorial scheme with four replications (first factor: two soybean cultivars - STS and no-STS; second factor: five periods between metsulfuron application and soybean sowing - 0, 15, 30, 45, and 60 days). At 7, 14, 21, and 28 days after sowing (DAS), an emergency evaluation of the soybean seedlings was performed; at 28 DAS, height and dry mass of the shoot were evaluated. The height averages for the STS cultivar were higher than the values of the no-STS cultivar. The average dry mass of soybean plants was higher in the STS cultivar at 0, 15, and 30 days between application and sowing. No differences were observed between the cultivars for the periods of 45 and 60 days, for average dry mass. The BMX soybean cultivar Garra RR2/STS was potentially tolerant for the pre-sowing application of the herbicide metsulfuron. The cultivar of M 6410 IPRO (non-STS) was affected in its initial development by the metsulfuron application during the pre-emergence stage; however, the 60-day metsulfuron application was safer, and therefore, it is recommended to perform the herbicide application in that interval.

RESUMEN

Palabras clave:
Herbicida
Pre-siembra
Tiempo de seguridad
STS

El metsulfurón se usa ampliamente para el manejo de malezas, sin embargo, el efecto residual en los cultivares de soja STS es desconocido. El objetivo de este trabajo fue evaluar el efecto residual del herbicida metsulfurón en los cultivares de soja BMX Garra RR2/STS y M 6410 IPRO (no-STS). El metsulfurón se aplicó a una dosis de 2,4 g i.a. ha^{-1}, en la pre-siembra de soja. El diseño experimental fue completamente aleatorio en un esquema factorial de 2x5 con cuatro repeticiones (primer factor: dos cultivares de soja - STS y no-STS y segundo factor: 5 períodos entre la aplicación y la siembra de soja - 0, 15, 30, 45 y 60 días). A los 7, 14, 21 y 28 días después de la siembra se realizó una evaluación de emergencia de las plántulas de soja, a los 28 días, se evaluó la altura y la masa seca de la parte aérea. Los promedios de altura para el cultivar STS fueron más altos que los valores del cultivar no-STS. La masa seca promedio de las plantas de soja fue mayor en el cultivar STS a los 0, 15 y 30 días entre la aplicación y la siembra. No se observaron diferencias entre los cultivares por los periodos de 45 y 60 días, para el promedio de masa seca. El cultivar de soja BMX Garra RR2/STS fue potencialmente tolerante para la aplicación previa a la siembra del metsulfurón. El cultivar de M 6410 IPRO (no-STS) tuvo su desarrollo inicial afectado por la aplicación de metsulfurón en preemergencia; sin embargo, la aplicación de metsulfurón de 60 días fue más segura y, por lo tanto, se recomienda realizar la aplicación de herbicida en ese intervalo de tiempo.

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Sulfonylurea tolerant soybean (STS®) is not a transgenic crop; it was developed by the technique of seed mutagenesis using the alkylating agent ethyl-methanesulfonate (EMS) (Walter *et al*., 2014). The EMS technique does not cause mutations by insertion into the DNA, but by modifying the already present base by introducing an alkyl radical (Rogozin *et al*., 2001). Mutant seeds from the soybean cultivar 'Williams 82' were selected according to tolerance to herbicide chlorsulfuron of the sulfonylurea group. Thus, the cultivar W20 was developed, which presented a high level of tolerance to some sulfonylureas (Sebastian *et al*., 1989; Walter *et al*., 2014).

Studies have indicated that this characteristic is determined by a semi-dominant allele that has been designated *Als1* and *Als2* (Sebastian *et al*., 1989; Ghio *et al*., 2013; Walter *et al*., 2014; Mantovani *et al*., 2017). The *Als1* allele confers tolerance to chlorimuron, nicosulfuron, rimsulfuron, sulfometuron, thifensulfuron, tribenuron, and flucarbazone while the *Als2* allele confers tolerance to these same herbicides and imazapyr (Walter *et al*., 2014). STS cultivars are highly tolerant to herbicide chlorimuron (Green, 2007; Albrecht *et al*., 2017; Albrecht *et al*., 2018), which can be applied up to four times –the recommended rate for non-STS cultivars (Roso and Vidal, 2011).

Sulfonylureas control mainly dicotyledonous weeds, and some herbicides demonstrate good action against Poaceae and Cyperaceae weeds. Thus, they are widely used to control weeds in soybean, maize, and other crops (Zhou *et al*., 2007).

The herbicide metsulfuron is used in Brazil for crops such as oats, wheat, sugarcane, among other monocotyledons and weed management in winter. The safety interval between application and sowing of soybeans is 60 days (Rodrigues and Almeida, 2018). The application of chlorsulfuron plus metsulfuron, 120 days before sowing (DBS), significantly affected soybean height and yield (non-STS cultivar) (Grey *et al*., 2012). However, there are no reports of the residual effect of metsulfuron on STS cultivars.

It is believed that the safety interval between application and sowing of STS soybeans is smaller than required for non-STS soybeans. The objective of this study was to evaluate the residual effect of herbicide metsulfuron on the BMX Garra RR2/STS and M 6410 IPRO (non-STS) soybean cultivars.

MATERIALS AND METHODS

The experiment was conducted in a greenhouse belonging to the Department of Crop Science of the University of São Paulo, 'Luiz de Queiroz' College of Agriculture, Piracicaba, State of São Paulo (SP), Brazil (22°42'32.0" S, 47°37'43.1" W), from November 2016 to February 2017.

The herbicide metsulfuron (Accurate®, 600 g kg^{-1}, FMC Química do Brasil Ltda., Brazil) was applied at a rate of 2.4 g of active ingredient (a.i.) ha^{-1}, before sowing soybean. The maximum recommended rate for weed control in winter management (off-season) (Rodrigues and Almeida, 2018).

The experiment was conducted in a 2×5 completely randomized factorial design, with four replications. The factors were composed of two soybean cultivars (STS and non-STS) and for five periods between application and sowing of soybean (0, 15, 30, 45, and 60 days). Soybean cultivars BMX Garra RR2/STS and M 6410 IPRO (non-STS) were used. The safety interval between application and sowing of soybeans is 60 days (Rodrigues and Almeida, 2018), which is why the periods chosen were a maximum of 60 days. Therefore, the 60 days are considered the control since it is safe for STS or non-STS soybean.

The experimental units were 5 L pots filled with medium texture soil (Table 1). Before the onset of the experiment, the two cultivars were subjected to a preliminary emergence test, with results higher than 90% at 15 days after sowing (DAS), for both.

At 60, 45, 30, 15, and 0 days, eight pots were applied at a time, four for each cultivar according to the periods between application and soybean sowing. After the application of the last period, the soybean cultivars BMX Garra RR2/STS and M 6410 IPRO (non-STS) were sown with ten seeds per pot, on January 5, 2017.

The applications were performed with a CO_2 pressurized backpack sprayer, bar-equipped with four spray nozzles, at a constant pressure of 200 kPa, a flow rate of 0.65 L min^{-1}, at the height of 50 cm from the target, and a speed of 1 m s^{-1}, with an applied band of 50 cm wide by a nozzle, delivering a spray volume of 200 L ha^{-1}.

Table 1. Result of the chemical and physical analysis of the soil used to fill the experimental units. Piracicaba, SP, Brazil, 2016/17.

pH ($CaCl_2$)	O.M. (g dm^{-3})	Al	H+Al	K	Ca	Mg	SB	CEC	P (resina) (mg dm^{-3})	V (%)
		(mmol$_c$ dm^{-3})								
5.3	42	<1.0	25.0	2.6	39.0	16	47.6	66.8	7.0	70

Clay	Silt	Sand
(%)		
35.0	7.0	58.0

At 7, 14, 21, and 28 DAS, soybean seedling emergence was evaluated. At 28 DAS, plant height was measured in all the plants in each pot and then averaging the plant height per pot. Also, at 28 DAS, the aerial part of all soybean plants was collected, the plant material was oven-dried at 65 °C for 72 h, and then the dry mass was recorded. The total dry mass per pot and mean dry mass per plant were determined.

Data were tested by analysis of variance and F-test (P<0.05), according to Pimentel-Gomes and Garcia (2002). For the soybean cultivar, the means were compared by Tukey's test (P<0.05) (Tukey, 1949). While for the period, the means were subjected to regression analysis (P<0.05). The Sivar 5.6 program was used for the analysis (Ferreira, 2011).

RESULTS AND DISCUSSION

There is a difference between cultivars in the emergence evaluation at 7 DAS (Figure 1). For the periods 0 and 15 days, between the application and sowing, the cultivar BMX Garra presented superior emergence than the cultivar M 6410 IPRO. For the other periods, no differences were detected between cultivars.

Similarly, differences between cultivars at 0 days were found in the emergence evaluation at 14 DAS (Figure 2). The cultivar STS showed a higher percentage of emergence in this period than the non-STS cultivar; for the other periods, no differences were observed between the cultivars.

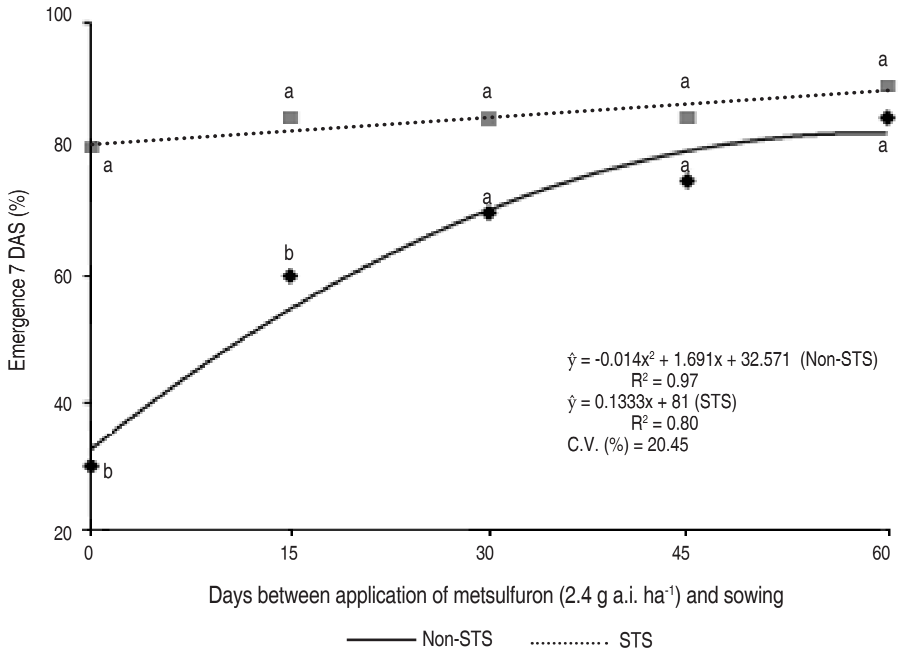

Figure 1. Emergence (%) of soybean plants at 7 DAS, under pre-sowing application of metsulfuron (2.4 g a.i. ha^{-1}). Piracicaba, SP, Brazil, 2016/17. Means with the same letters, comparing cultivars, do not differ by Tukey test (P<0.05).

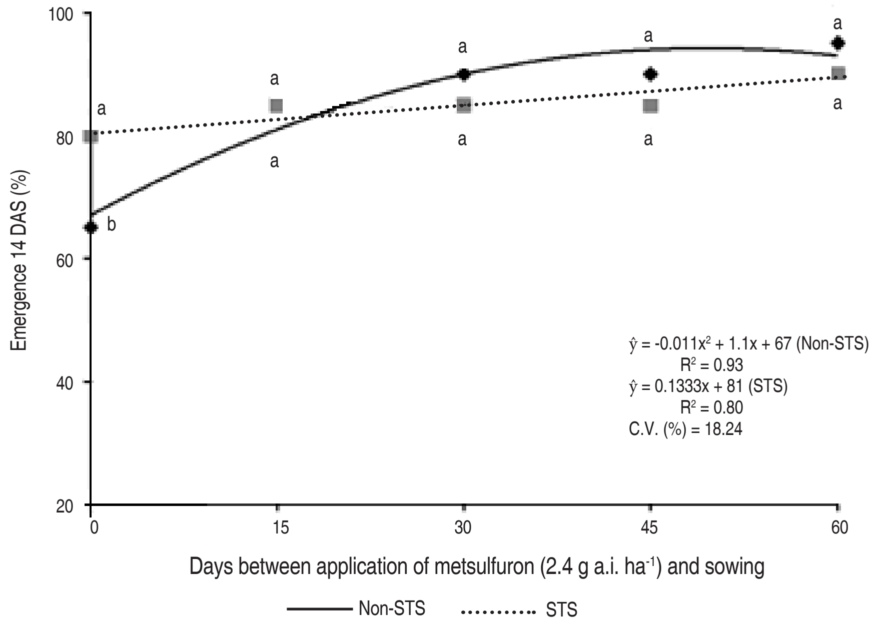

Figure 2. Emergence (%) of soybean plants at 14 DAS, under pre-sowing application of metsulfuron (2.4 g a.i. ha^{-1}). Piracicaba, SP, Brazil, 2016/17. Means with the same letters, comparing cultivars, do not differ by Tukey test (*P*<0.05).

For the emergence of STS cultivar, at 7 and 14 DAS, it was possible to fit a linear regression; with the decrease of days in the period between application and sowing, the emergence percentage was lower. For the emergence of non-STS cultivar, at 7 and 14 DAS, it was possible to fit a polynomial. Despite the fit, 80.0% emergence occurs at 7 DAS for the STS cultivar (0 d between application and sowing), which is at the recommended minimum limit for seed commercialization (MAPA, 2009). While for the non-STS cultivar, the emergence percentage at 7 DAS was only 30.0% for the same period.

It should be noted that the emergence evaluation was also performed at 21 and 28 DAS (data not shown). However, they were not subjected to statistical analysis since the percentages remained constant from the evaluation at 14 DAS.

For the height of plants (Figure 3), it can be observed that for all periods, values for the STS cultivar were higher than the values of the non-STS cultivar. For the non-STS cultivar, it was possible to fit an upward linear regression, with the increase of days between the application and sowing, the plants' mean height of the increases. While for the STS cultivar, it was not possible to fit a linear regression according to the observed criteria (biological explanation, significant regression, non-significant deviations from regression, coefficient of determination, and residual analysis).

For the variables total dry mass (Figure 4) and mean dry mass (Figure 5), for the STS cultivar, it was not possible to fit a linear regression according to the observed criteria (biological explanation, significant regression, non-significant deviations from regression, coefficient of determination, and residual analysis). It is evidence of the tolerance of the BMX Garra cultivar to the herbicide metsulfuron in pre-sowing, regardless of the period in days, between application and sowing.

However, for the non-STS cultivar, it was possible to fit a linear regression; decreasing the days between application and sowing, the total and mean dry mass of soybean plants also decrease. It should be noted that in the comparison between cultivars, it is not verified difference only for the period of 60 days, for total dry mass. In other periods, the STS cultivar always had the highest total dry mass (Figure 4).

For the mean dry mass of soybean plants, it was observed that, in the comparison between cultivars, the

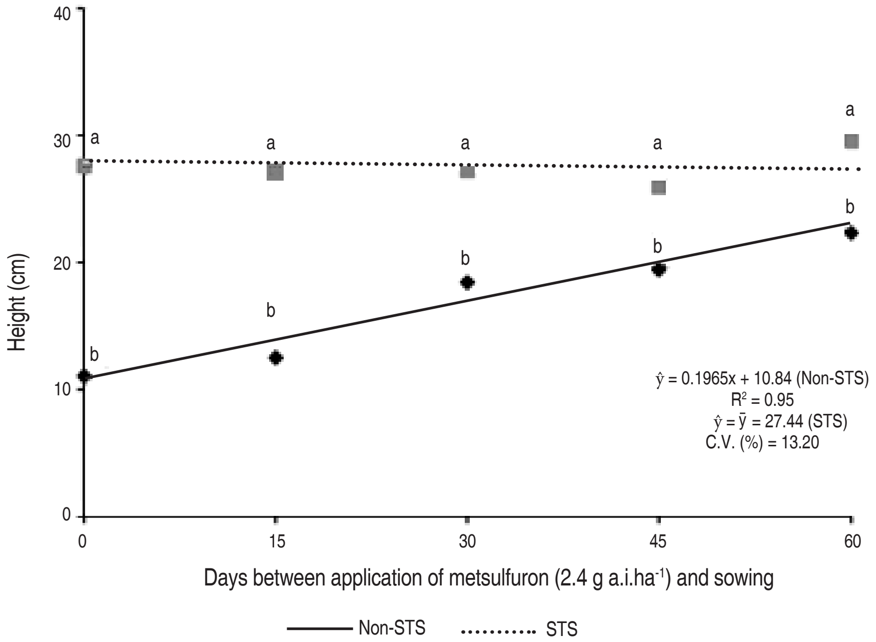

Figure 3. Height (cm) of soybean plants at 28 DAS, under pre-sowing application of metsulfuron (2.4 g a.i. ha^{-1}). Piracicaba, SP, Brazil, 2016/17. Means with the same letters, comparing cultivars, do not differ by Tukey test (*P*<0.05).

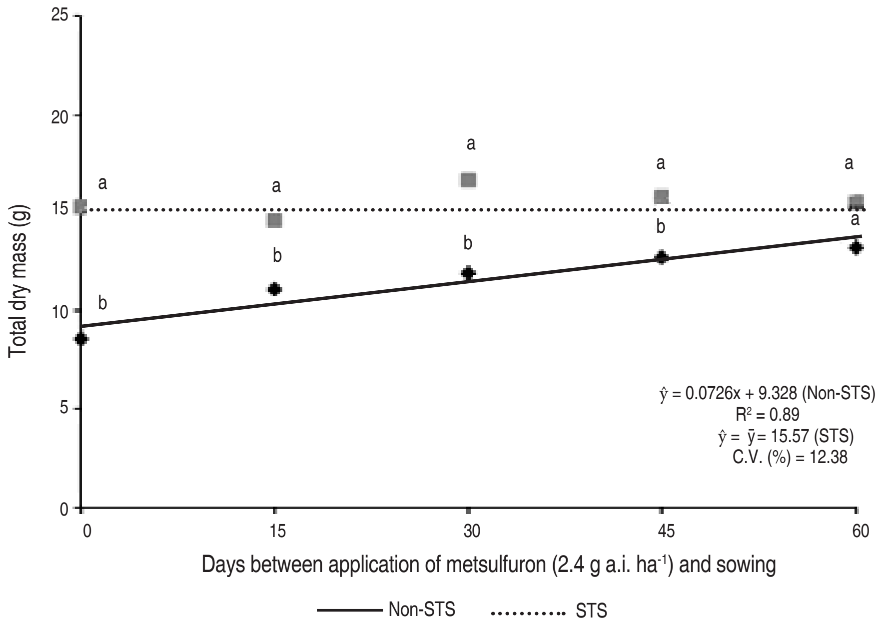

Figure 4. Total dry mass (g) of aerial part soybean plants at 28 DAS, under pre-sowing application of metsulfuron (2.4 g a.i. ha^{-1}). Piracicaba, SP, Brazil, 2016/17. Means with the same letters, comparing cultivars, do not differ by Tukey test (*P*<0.05).

cultivar STS was superior to non-STS for periods of 0, 15, and 30 days between application and sowing. No differences were detected between the cultivars for the periods of 45 and 60 days (Figure 5).

Studies have reported tolerance of STS cultivars for application of the following sulfonylureas: chlorimuron (Poston *et al*., 2008; Silva *et al*., 2016; Albrecht *et al*., 2017; Albrecht *et al*., 2018) and prosulfuron (Anderson and Simmons, 2004), thifensulfuron (Esbenshade *et al*., 2001), nicosulfuron (Manley *et al*., 2001; Silva *et al*., 2016; Albrecht *et al*., 2017; Silva *et al*., 2018; Silva *et al*., 2019), halosulfuron (Nandula *et al*., 2009), trifloxysulfuron (Porterfield *et al*., 2006), sulfometuron (Piasecki and Rizzardi, 2016) and metsulfuron (Merotto Júnior *et al*., 2000; Albrecht *et al*., 2017). Although there are reports of tolerance to herbicide metsulfuron in some STS cultivars, Silva *et al.* (2016) did not verify tolerance, for post-emergence application, in the cultivar CD 2630 RR/STS.

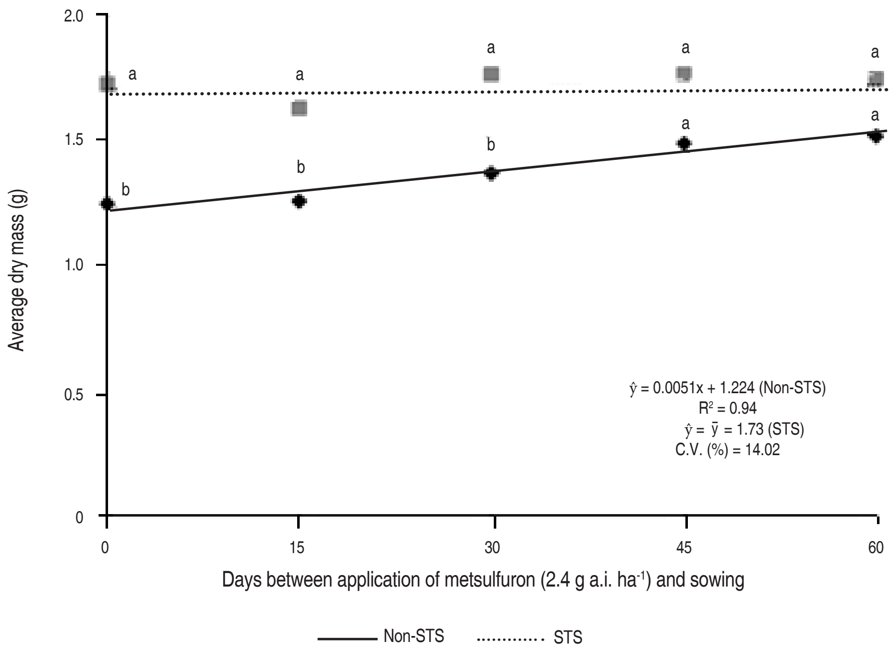

Figure 5. Average dry mass (g) of aerial part soybean plants at 28 DAS, under pre-sowing application of metsulfuron (2.4 g a.i. ha^{-1}). Piracicaba, SP, Brazil, 2016/17. Means with the same letters, comparing cultivars, do not differ by Tukey test (*P*<0.05).

For non-STS cultivars, the safety interval between application and sowing is 60 days (Rodrigues and Almeida, 2018). In the present study, the cultivar M 6410 IPRO (non-STS) had its initial development impaired by the pre-emergence application of the herbicide metsulfuron. It was possible to fit a regression model for all analyzed variables, reducing the values with a decrease of the days between application and sowing. According to the results, reductions are observed in some STS's variables from 45 days between application and sowing. For the interval of 60 days, in general, no differences are found between the cultivars, also for 60 days, an emergence of 85 and 95% was observed, at 7 and 14 DAS, respectively, for non-STS. Values above of recommended minimum (80%) for seed commercialization (MAPA, 2009).That is, the pre-sowing application of metsulfuron is safe for the non-STS cultivar when the safety interval is respected.

In pre-emergence, there are no reports of selectivity of the herbicide metsulfuron in STS soybean, the results obtained in the present study are of great importance in the positioning of the herbicide metsulfuron in pre-emergence of STS soybean. The results indicate that the cultivar BMX Garra RR2/STS is potentially tolerant of metsulfuron, regardless of the period between application and sowing. Only for the emergence, it was possible to fit a regression; however, even for sowing immediately after application, the emergence percentages were 80.0%.

The herbicide metsulfuron has a broad spectrum of action, controlling mainly eudicotyledons plants and some species of monocotyledons (Rodrigues and Almeida, 2018). The herbicide, alone or in combination, is effective in the control of *Conyza bonariensis* (Vargas *et al*., 2007; Walker *et al*., 2013), *Fimbristylis miliacea*

(Tormena *et al*., 2016), *Hordeum spontaneum* (Izadi-Darbandi and Aliverdi, 2015), *Cirsium arvense* (Zargar *et al*., 2019), among others.

Thus, the herbicide metsulfuron can be used in the management of weeds, especially eudicotyledons plants resistant or naturally tolerant to glyphosate in pre-sowing of STS soybean. In this context, STS cultivars can be of great importance in the management and prevention of the selection of herbicide-resistant biotypes weeds, due to the possibility of using other herbicides (Green, 2007; 2012). As well as the use of the herbicide metsulfuron, in pre-emergence, according to these results. Studies indicate that the use of pre-emergence herbicides, in combination with other management practices, is effective in the control of weeds in soybean crops, as well as in the prevention of the selection of resistant weed biotypes (Neve *et al*., 2018; Rosario-Lebron *et al*., 2019).

CONCLUSIONS

The soybean cultivar BMX Garra RR2/STS, in general, was potentially tolerant to the herbicide metsulfuron, applied at pre-sowing. Therefore, sowing can be done immediately after the application. The cultivar M 6410 IPRO (non-STS) had its initial development impaired by the pre-emergence application of the herbicide metsulfuron. However, when the safety interval recommended (60 days) is respected, the application of the herbicide is safe to the cultivar.

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