Revista Ciência Agronômica, v. 53, e20218175, 2022
Centro de Ciências Agrárias - Universidade Federal do Ceará, Fortaleza, CE
www.ccarevista.ufc.br

Scientific Article
ISSN 1806-6690

Glufosinate, nicosulfuron and combinations in the performance of maize hybrids with the *pat* gene[1]

Glufosinate, nicosulfuron e associações no desempenho de híbridos de milho com gene *pat*

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ABSTRACT - Combinations of glufosinate with nicosulfuron, among other post-emergent herbicides, are promising for weed control in maize. However, some of these herbicides can cause injury and have other undesirable effects on the maize, so it is necessary to investigate their selectivity for cultivation. The aim of this study was to evaluate the selectivity of glufosinate, nicosulfuron and combinations, by analysing the agronomic performance of the crop for post-emergent application in maize hybrids with the *pat* gene. Two experiments were conducted in the state of Paraná, Brazil, during the 2019/2020 season, in a 2 x 8 (exp. I) and 2 x 4 (exp. II) factorial scheme. Two hybrids were used (FS505 PWU and FS715 PWU), with eight levels for the factor herbicide in experiment I (glufosinate, halosulfuron and glufosinate in combination with halosulfuron, nicosulfuron, atrazine, tembotrione or mesotrione, in addition to the control with no application) and four levels of herbicide in experiment II (nicosulfuron in two formulations, mesotrione, and the control). Injury to the maize plants and variables related to agronomic performance were evaluated. Although the herbicides had no effect on yield, it can be inferred that FS505 is more sensitive to nicosulfuron and mesotrione than is FS715, since the injury was greater than seen in FS715. The post-emergent application of glufosinate, nicosulfuron and combinations is selective for the FS505 PWU and FS715 PWU hybrids (with the *pat* gene). Despite injury, which was more pronounced in the FS505 PWU hybrid, there was no negative impact on yield or on other the variables of agronomic performance.

Key words: *Zea mays* L. Tank mixture. Mesotrione. Halosulfuron. Yield.

RESUMO - As associações de glufosinate com nicosulfuron, entre outros herbicidas, são promissoras no controle de plantas daninhas em pós-emergência do milho. Contudo alguns desses herbicidas podem causar injúrias e causar outros efeitos indesejáveis ao milho, assim é preciso se investigar a seletividade para o cultivo. Objetivou-se avaliar a seletividade de glufosinate, nicosulfuron e associações, em análise do desempenho agronômico do cultivo, para a aplicação em pós-emergência de híbridos de milho com gene *pat*. Dois experimentos foram conduzidos no estado do Paraná, Brasil, safra 2019/2020, em arranjo fatorial 2 x 8 (exp. I) e 2 x 4 (exp. II). Dois híbridos (FS505 PWU e FS715 PWU), oito níveis para o fator herbicida no experimento I (glufosinate, halosulfuron e glufosinate em associações com halosulfuron, nicosulfuron, atrazine, tembotrione ou mesotrione, além da testemunha sem aplicação) e quatro níveis para herbicidas no experimento II (nicosulfuron em duas formulações, mesotrione, além da testemunha) foram utilizados. Injúria nas plantas de milho e variáveis relacionadas ao desempenho agronômico foram avaliadas. Embora os herbicidas não tenham influenciado a produtividade, pode-se inferir que FS505 é mais sensível ao nicosulfuron e mesotrione que FS715, uma vez que a injúria observada foi maior que os observados em FS715. A aplicação em pós-emergência de glufosinate, nicosulfuron e associações é seletiva para os híbridos FS505 PWU e FS715 PWU (com gene *pat*). Apesar das injúrias, mais pronunciadas no híbrido FS505 PWU, não se observa impacto negativo sob a produtividade e outras variáveis de desempenho agronômico.

Palavras-chave: *Zea mays* L. Mistura de tanque. Mesotrione. Halosulfuron. Produtividade.

DOI: 10.5935/1806-6690.20220046
Editor-in-Chief: Salvador Barros Torres - sbtorres@ufersa.edu.br
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Received for publication 26/11/2021; approved on 17/02/2022
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INTRODUCTION

Weeds can generate large losses in agricultural production even at low densities, and are one of the main factors that interfere in the development and yield of crops. In maize cultivation, losses from weed competition can range from 18% to more than 90%, and depend mainly on the weed community, the hybrid, and the soil and climate conditions (GHARDE *et al*., 2018; KARKANIS *et al*., 2020).

Different methods can be used for controlling weeds, in particular chemical control (herbicides). However, attention should be paid to the selectivity of the herbicide for the plant being cultivated. Selectivity is a differential response of the crop to the application of a herbicide, which may or may not suffer injury. Such injury can be of differing intensity according to the crop, application conditions, and the physiological state and morphology of the plant. Selectivity is also related to the plant's ability to recover after the application of a herbicide, through inactivation or metabolisation of the molecule (CARVALHO *et al*., 2009).

In this context, transgenic cultivars that show tolerance to herbicides due to the presence of a gene from another organism are important. The transgenic events, T25 and T14, confer tolerance on the herbicide glufosinate in maize (Liberty Link™ - LL); this tolerance is afforded by the *pat* gene, from the bacterium *Streptomyces viridochromogenes*. The gene encodes the phosphinothricin *N*-acetyltransferase (PAT) enzyme, which metabolises glufosinate into the compound *N*-acetyl-l-glufosinate (NAG) that is not toxic to plants (MÜLLNER; ECKES; DONN, 1993). The *pat* gene was used as a marker in the selection process for insect-resistant maize events (Bt11 and TC1507) (GREEN, 2009). Therefore, these events, together with other combinations, are also glufosinate tolerant (NANDULA, 2019).

The post-emergent application of glufosinate is used to control weeds in maize hybrids with this technology. In general, maize hybrids are tolerant to glufosinate, albeit with possible symptoms of injury, especially when applying doses greater than recommended by the manufacturer, but with no loss of yield (ARAÚJO *et al*., 2021; KRENCHINSKI *et al*., 2018).

Other herbicides are widely used for controlling weeds in maize, for example, atrazine, nicosulfuron, and carotenoid synthesis inhibitor herbicides such as mesotrione and tembotrione. Studies highlight the selectivity of these herbicides for maize (GIOVANELLI *et al*., 2018; GIRALDELI *et al*., 2019); however, the plants eventually show symptoms of injury, especially to nicosulfuron, with sensitivity differing between hybrids (CAVALIERI *et al*., 2008; WANG *et al*., 2018).

Combinations of glufosinate with other post-emergent herbicides used in maize, for example nicosulfuron and mesotrione, are promising for controlling weeds. But considering that some of these herbicides may cause injury and have other undesirable effects on the maize, it is necessary to investigate the selectivity of glufosinate, nicosulfuron and combinations. Other studies have evaluated the effects of these herbicides on maize (KRENCHINSKI *et al*., 2019; SILVA *et al*., 2017). It is believed that the selectivity of such herbicide combinations may vary according to the maize hybrid.

As such, the aim of this study was to evaluate the selectivity of the post-emergent application of glufosinate, nicosulfuron and their combination with halosulfuron, atrazine, tembotrione and mesotrione, by analysing the agronomic performance of maize hybrids with the *pat* gene.

MATERIAL AND METHODS

Two experiments were carried out in the field in the state of Paraná (PR), Brazil, between September 2019 and March 2020. experiment I was conducted in Palotina (24º17'S, 53º50'W, altitude 330 m) in a Eutroferric Red Latosol of a highly clayey texture (20% sand, 18.75% silt, 61.25% clay) with a CEC of 14.51 $cmol_c\ dm^{-3}$ and pH (H_2O) of 6. According to the Köppen-Geiger classification, the climate in the region is characterised as Cfa (humid subtropical mesothermal), with an average temperature of 15 ºC in the winter and up to 37 ºC in the summer and an average annual rainfall of 1,650 mm. experiment II was conducted in Ponta Grossa (25º09'S, 50º04'W, altitude 958 m) in a typical dystrophic Red Latosol of medium texture (59.5% sand, 7.2% silt, 33.3% clay) with a CEC of 10.15 $cmol_c\ dm^{-3}$ and pH (CaCl) of 5.4. According to the Köppen-Geiger classification, the climate in the region is classified as Cfb (humid subtropical), with an average temperature of 14 ºC in the winter and up to 22 ºC in the summer and rainfall of 1,505 mm $year^{-1}$. The weather conditions during the experimental period are shown in Figure 1.

The maize was sown by hand in plots of 5 x 2.7 m. For experiment I, sowing took place on 28/9/2019 in six rows per plot, spaced 0.45 m apart, at a density of 62,200 plants ha^{-1}. For experiment II, sowing took place on 16/10/2019 in 6 rows per plot, at a spacing of 0.5 m and a density of 65,000 plants ha^{-1}. Faced with periods of drought when conducting the experiments, the area received complementary irrigation to ensure good crop development. Irrigation was by sprinkler, in five applications, each with an irrigation depth of 12 mm.

In experiment I, the treatments were arranged in a 2 x 8 factorial scheme, with two maize hybrids (FS505 and FS715) and eight levels of herbicide, consisting of individual applications or a tank mixture (Table 1). For experiment II, in a 2 x 4 factorial scheme, two maize hybrids (FS505 and FS715) and four levels of herbicide were used (Table 1). A randomised block design was employed, with four replications in experiment I and three replications in experiment II.

The FS505 and FS715 single hybrids show high productive potential and feature Power Core™ Ultra - PWU technology (the MON89034 x TC1507 x NK603 x MIR162 event). This attribute confers tolerance on the herbicides glyphosate (due to the *cp4epsps* gene) and glufosinate (due to the *pat* gene) (ALBRECHT *et al*., 2021).

The treatments were applied at the V4 stage, directly on the maize plants. A backpack sprayer pressurised with CO_2 was used, equipped with a 3 m boom, six TT 110.02 nozzles, spaced 0.5 m apart and 0.5 m from the maize plants, at an application volume of 150 L ha^{-1}. In Experiment I, the application took place on 29/10/2019 at a temperature of 21.6 ºC, relative humidity of 68.2% and average wind speed of less than 5 km h^{-1}. For experiment II, application was on 07/11/2019 at a temperature of 20.3 ºC, relative humidity of 70.4% and average wind speed of less than 5 km h^{-1}. To keep the plots free from weed interference, escapes were controlled by manual weeding.

Figure 1 - Rainfall, and maximum and minimum temperature for the experimental period in the districts of Palotina and Ponta Grossa, PR, 2019/2020 crop

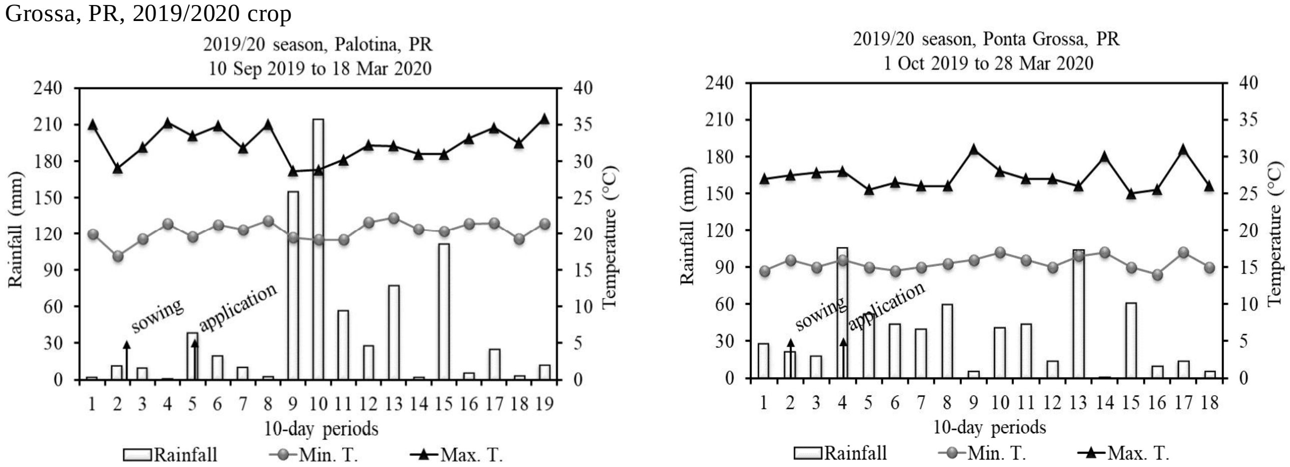

Table 1 - Levels of herbicide in individual post-emergent applications or a tank mixture, in maize hybrids, 2019/2020 season

	Herbicide	Commercial product	Dose¹
			g a.i. ha^{-1}
Experiment I	Glufosinate	Finale®	500
	Halosulfuron	Sempra®	75
	Glufosinate + halosulfuron	Finale® + Sempra®	500 + 75
	Glufosinate + nicosulfuron	Finale® + Sanson® 40 SC	500 + 60
	Glufosinate + atrazine	Finale® + Atrazina Atanor® 50 SC	500 + 2,500
	Glufosinate + tembotrione	Finale® + Soberan®	500 + 100.8
	Glufosinate + mesotrione	Finale® + Callisto®	500 + 192
	Control (no application)	-	-
Experiment II	Nicosulfuron	Accent®	45
	Nicosulfuron	Sanson® 40 SC	52
	Mesotrione	Callisto®	192
	Control (no application)	-	-

The addition of Aureo® adjuvant (0.3% v:v) in all applications except the individual application of halosulfuron. ¹a.i.: active ingredient

Crop injury were evaluated at 7, 14, 21 and 28 days after applying the herbicide (DAA). Grades were assigned by visual analysis (0 for no injury, 100% for plant death), considering significantly visible symptoms in the plants based on their development (VELINI; OSIPE; GAZZIERO, 1995).

For agronomic performance, plant height, ear insertion height, stem diameter and yield were evaluated. To assess the height, 10 plants were measured per plot, taking the distance between the base of the plant close to the ground to the point of insertion of the last leaf (flag) or ear. The stem diameter was determined in experiment I only, measuring 10 plants per plot using a digital calliper. The plants in the working area of each plot were harvested manually, the grains were threshed, and their weight measured and corrected for 13% moisture, with yield expressed in kg ha^{-1}.

The data were submitted to analysis of variance (ANAVA) by F-test ($p \leq 0.05$). The F-test was conclusive in comparing hybrid levels. The levels of herbicide were compared by Tukey's test at a level of 5%. The Sisvar 5.6 software was used (FERREIRA, 2011).

RESULTS AND DISCUSSION

For crop injury in experiment I, the ANAVA results by F-test indicated a significant effect for the maize hybrids, herbicides, and interaction between the factors ($p \leq 0.05$). In general, when differences were found in the breakdown between hybrids, greater symptoms were seen in plants of the FS505 hybrid. At 28 DAA, greater symptoms of injury were seen with the application of glufosinate + nicosulfuron (17.3%) in the FS505 hybrid, while in the FS715 hybrid, even with the application of glufosinate + nicosulfuron, the injury seen was 9%. Another result to be noted is that the individual application of halosulfuron caused at most 4% injury at 28 DAA, with no difference between hybrids. While for the combination of glufosinate + halosulfuron, there was up to 8.5% injury at 28 DAA, also with no difference in the sensitivity of the hybrids (Table 2).

Furthermore, for experiment I, ANAVA indicated no significant effect for yield or other variables related to agronomic performance, whether for the hybrids, herbicides or the interaction. However, an exception was seen for ear insertion height, with a difference between hybrids only, and no effect from the herbicides or interaction (data not shown). These results demonstrate the selectivity of the herbicides for the maize plants, showing no differences between the hybrids, and despite symptoms of injury, no negative impact on yield.

In experiment II, the FS505 hybrid showed the most symptoms of injury, especially with the application of

Table 2 – Crop injury at 7, 14, 21 and 28 days after application (DAA) of post-emergent herbicides in maize plants, Palotina, PR, 2019/2020 (experiment I)

Herbicide	Hybrids							
	FS505	FS715	FS505	FS715	FS505	FS715	FS505	FS715
	7 DAA		14 DAA		21 DAA		28 DAA	
	%							
Glufosinate (glu)	6.3 Bbc	2.3 Aa	6.0 Aab	5.8 Aab	5.0 Abc	5.3 Abcd	2.3 Aab	2.3 Aab
Halosulfuron	10.8 Ac	8.0 Ab	7.5 Abc	5.8 Aab	6.8 Bbc	3.5 Aabc	4.0 Ab	2.8 Aab
Glu + halosulfuron	16.0 Ad	17.3 Ac	11.5 Abc	14.0 Ac	9.5 Acd	9.8 Ade	8.5 Ac	6.8 Acd
Glu + nicosulfuron	25.3 Be	16.8 Ac	23.5 Bd	14.0 Ac	20.3 Be	12.8 Ae	17.3 Bd	9.0 Ad
Glu + atrazine	4.0 Aab	4.5 Aab	5.5 Aab	6.8 Ab	5.8 Abc	7.8 Acd	3.0 Aab	4.0 Abc
Glu + tembotrione	4.3 Aab	4.3 Aab	5.8 Aab	4.0 Aab	4.0 Aab	2.5 Aab	2.8 Aab	1.5 Aab
Glu + mesotrione	21.0 Be	16.0 Ac	13.5 Ac	13.8 Ac	11.8 Ad	13.0 Ae	8.8 Ac	8.5 Ad
Control (no application)	0.0 Aa	0.0 Aa	0.0 Aa	0.0 Aa	0.0 Aa	0.0 Aa	0.0 Aa	0.0 Aa
F hybrids	*		*		*		*	
F herbicides	*		*		*		*	
F hybrids x herbicides	*		*		*		*	
CV%	22.7		31.7		27.9		26.8	
Mean	9.8		8.6		7.3		5.1	

Mean values followed by the same uppercase letter in the comparison between hybrids, do not differ by F-test at a level of 5%. Mean values followed by the same lowercase letter in the comparison between herbicides, do not differ by Tukey's test at a level of 5%

mesotrione and nicosulfuron (Sanson® 40 SC). For FS505, all the treatments differed from the control (no application). Whereas for FS715 from 14 DAA, nicosulfuron (Accent®) showed no difference from the control treatment; the same as mesotrione at 28 DAA. Furthermore, at 28 DAA, no herbicide caused more than 10% injury in the FS715 hybrid, while for FS505, more than 10% injury was caused by the application of mesotrione or nicosulfuron (Sanson® 40 SC) (Table 3).

For plant height and yield, ANAVA indicated a significant effect for the maize hybrids only, with no effect for the herbicides (data not shown). While for ear insertion height, a significant effect was found for both factors, as well as for the interaction. The application of mesotrione reduced the ear insertion height in the FS505 hybrid, in line with that seen for injury. The herbicides had no effect on ear insertion height in the FS715 hybrid (Table 4).

Table 3 – Crop injury at 7, 14, 21 and 28 days after application (DAA) of post-emergent herbicides in maize plants, Ponta Grossa, PR, Brazil, 2019/2020 (experiment II)

Herbicide	Hybrids							
	FS505	FS715	FS505	FS715	FS505	FS715	FS505	FS715
	7 DAA		14 DAA		21 DAA		28 DAA	
	%							
Nicosulfuron (Accent®)	20.0 Bb	6.7 Ab	21.7 Bb	6.7 Aab	20.0 Bb	1.7 Aa	6.7 Bb	0.0 Aa
Nicosulfuron (Sanson® 40 SC)	23.3 Bb	10.0 Abc	38.3 Bc	16.7 Ac	30.0 Bc	16.7 Ac	11.7 Bc	6.7 Ab
Mesotrione	30.0 Bc	13.3 Ac	46.7 Bc	13.3 Abc	40.0 Bd	10.0 Ab	15.0 Bc	1.7 Aa
Control (no application)	0.0 Aa	0.0 Aa	0.0 Aa	0.0 Aa	0.0 Aa	0.0 Aa	0.0 Aa	0.0 Aa
F hybrids	*		*		*		*	
F herbicides	*		*		*		*	
F hybrids x herbicides	*		*		*		*	
CV%	20.47		23.49		16.29		29.63	
Mean	12.92		17.92		14.79		5.21	

Mean values followed by the same uppercase letter in the comparison between hybrids, do not differ by F-test at a level of 5%. Mean values followed by the same lowercase letter in the comparison between herbicides, do not differ by Tukey's test at a level of 5%

Table 4 - Ear insertion height in maize plants under the application of herbicides, Ponta Grossa, PR, Brazil, 2019/2020 (experiment II)

Herbicide	Hybrids	
	FS505	FS715
	Ear insertion height	
	cm	
Nicosulfuron (Accent®)	1.28 Ba	1.41 Aa
Nicosulfuron (Sanson® 40 SC)	1.24 Bab	1.35 Aa
Mesotrione	1.12 Bb	1.41 Aa
Control (no application)	1.27 Ba	1.37 Aa
F hybrids	*	
F herbicides	*	
F hybrids x herbicides	*	
CV%	4.13	
Mean	1.31	

Mean values followed by the same uppercase letter in the comparison between hybrids, do not differ by F-test at a level of 5%. Mean values followed by the same lowercase letter in the comparison between herbicides, do not differ by Tukey's test at a level of 5%

The selectivity of glufosinate for maize, whether individually or in combination, has been found in other studies (GANIE; JHALA, 2017; LINDSEY *et al*., 2012); the maize hybrids were T14 or T25 events with the same LL technology, which guarantees the plants a good level of tolerance. In this study, selectivity was also found for insect-resistant hybrids, as seen by Krenchinski *et al*. (2019). The selectivity of glufosinate for maize with different technologies was found in other studies, with varying degrees of injury and with no reduction in yield (KRENCHINSKI *et al*., 2020; SILVA *et al*., 2017). In addition to the hybrid, therefore, transgenic technology can also affect plant response, which is related to the level of expression of the *pat* gene (KRENCHINSKI *et al*., 2018, 2020).

Injury of less than 5% was found in maize with the *pat* gene from the application of glyphosate (1,080 g acid equivalent [a.e.] ha^{-1}), glufosinate (500 g a.i. ha^{-1}) and atrazine (2,000 g a.i. ha^{-1}), individually and in combination (SILVA *et al*., 2017). Furthermore, the application of glufosinate + atrazine in various management combinations did not generate different levels of yield than the combinations of glyphosate + atrazine, tembotrione + atrazine or nicosulfuron + atrazine (GEMELLI *et al*., 2013). The results of the present study corroborate those cited above, confirming the tolerance of insect-resistant maize to glufosinate and its combinations.

Glufosinate selectivity was verified in the present study, with no differences in injury between the hybrids. More serious symptoms were observed for the combinations with nicosulfuron and mesotrione, and at the higher levels in some of the combinations applied to the FS505 hybrid. Despite not differing from the control for yield, applying glufosinate + nicosulfuron to the FS505 hybrid resulted in greater injury. This combination constitutes an alternative for weed control in maize, but should be analysed with caution in view of the greater injury caused.

In experiment II, differences were seen in the injury caused by the two products based on nicosulfuron. Any difference in the commercial product, or dose or concentration of the oil/adjuvant in the application mixture can affect the level of selectivity of nicosulfuron in maize (MACIEL *et al*., 2018). The selectivity of this herbicide among hybrids is variable, and may be affected by the stage of plant development (MEYER; PATAKY; WILLIAMS, 2010).

Nicosulfuron shows varying selectivity between hybrids, period of application and dose. Injury can be increased by combining nicosulfuron with insecticides of the organophosphate group, due to the inhibition of the cytochrome P450 enzyme, which results in less metabolism of the nicosulfuron (LIU *et al*., 2015; MEYER; PATAKY; WILLIAMS, 2010). In maize plants, this enzyme is linked to the metabolism of nicosulfuron, which in greater amounts helps to explain the differences in tolerance between hybrids (LIU *et al*., 2015). In some varieties of sweet corn, the CYP81A9 enzyme is also responsible for metabolising nicosulfuron, which affords greater tolerance to the herbicide (CHOE; WILLIAMS, 2020); these characteristics may therefore be related to the responses of the hybrids to the herbicides used in this study.

Halosulfuron is an ALS inhibitor from the group of sulfonylureas, as is nicosulfuron. This herbicide is not registered for maize cultivation in Brazil, but its selectivity and/or effectiveness in controlling weeds in maize has been verified (SOLTANI *et al*., 2018). Halosulfuron is commonly used in sugar cane to control *Cyperus* spp. (GIRALDELI *et al*., 2020). In this study, the application of halosulfuron had no negative effect on the maize plants, with a lower potential for injury than nicosulfuron. This shows its possible use in expanding the choice of herbicides in maize, especially as an alternative to nicosulfuron in the more sensitive hybrids.

A difference in sensitivity between the hybrids was also found for mesotrione, again with a greater negative effect on FS505, even including a reduction in ear insertion height. In other studies, the pre- and post-emergent application of mesotrione in maize showed differing responses for herbicide selectivity, highlighting that mesotrione may or may not cause injury to the maize, and that when injury occurs, it does not always affect yield (ARMEL *et al*., 2003; MESAROVIĆ *et al*., 2019; MEYER; PATAKY; WILLIAMS, 2010).

The literature shows varying responses to the application of mesotrione and/or nicosulfuron in maize, whether individually or combined with glyphosate, atrazine, tembotrione and others, with or without symptoms of injury to the plants, but with no impact on the production components or yield (CAVALIERI *et al*., 2008; GIRALDELI *et al*. 2019; JAGŁA *et al*., 2020; RICHBURG *et al*., 2020). As seen in the present study, even combining glufosinate and mesotrione can cause injury of up to 20% in maize plants (ARMEL *et al*., 2008) with no reduction in yield. It’s also important to note the influence of other factors, such as the hybrid, climate conditions, application technology, etc, on weed management in maize.

Despite being widely used for weed management in maize, Mesotrione also presents varying levels of selectivity due to the type of maize hybrid and the method of applying the herbicide. This herbicide has less impact on maize because of its faster metabolism, as described for nicosulfuron; this may be related to its varying selectivity and the differing responses to the application of nicosulfuron and mesotrione. Although these herbicides are selective, under certain conditions, nicosulfuron and mesotrione can cause injury that may or may not affect yield (ÁVILA *et al*., 2017). In fact, the genetic basis for the enzymatic expression of nicosulfuron tolerance may also be related to mesotrione tolerance: for example, the P450 enzyme is also responsible for the metabolism of mesotrione (CHOE; WILLIAMS, 2020; MEYER; PATAKY; WILLIAMS, 2010).

The herbicides had no effect on yield in the hybrids, but it can be inferred that FS505 is more sensitive to nicosulfuron and mesotrione than is FS715, as the values for injury were higher in FS505 (up to 46.7%) than those observed in FS715 (less than 20%). Therefore, carrying out studies like this is important to generate more information about the selectivity of individual or combined products for weed management in maize.

The interaction between environment, crop and product should be taken into consideration when recommending the application of herbicides. All aspects inherent to these factors should also be considered, such as the dose, period of application and sensitivity of the hybrid. It is therefore necessary to carry out further studies at field level to generate this information, since there remain many possibilities for weed management still to be raised.

CONCLUSIONS

Post-emergent application in maize plants of the herbicides glufosinate, nicosulfuron and combinations of glufosinate with halosulfuron, nicosulfuron, atrazine, tembotrione or mesotrione is selective for the FS505 PWU and FS715 PWU maize hybrids (with the *pat* gene). Despite injury, which was more pronounced in the FS505 PWU hybrid, there was no impact on yield or on other variables of agronomic performance.

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