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Article

Characterization of Ethoxysulfuron Herbicide Selectivity in Common Bean Cultivars

Caracterização da Seletividade do Herbicida Ethoxysulfuron em Cultivares de Feijão Comum

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ABSTRACT - In literature, there are few studies evaluating the response of different bean cultivars to herbicides, particularly the ALS enzyme inhibitors. The objective of this study was to evaluate the selectivity of common bean cultivars to the herbicide ethoxysulfuron and to select cultivars that are more tolerant to it. An experiment was conducted in a greenhouse, in a completely randomized experimental design with four replications. Factors consisted in 20 bean cultivars (IPR Eldorado, IPR Siriri, IPR Gralha, IPR 81, IPR Uirapuru, IPR Colibri, IPR Tuiuiú, BRS Esplendor, IPR Tangará, IPR Juriti, IPR Corujinha, IPR Andorinha, IPR Curió, BRS Campeiro, BRS Pérola, BRS Notável, BRS Estilo, UTF 3, UTF 5 e UTF 6), and four doses of ethoxysulfuron (0, 50, 100 and 200 g ha^{-1}) were used. At the dose of 200 g ha^{-1}, the reduction of the shoot dry matter of plants ranged from 30 to 80%, indicating that there was high variability in the response of bean cultivars to the herbicide. The bean cultivars classified as more tolerant to ethoxysulfuron are: IPR 81, IPR Uirapuru, BRS Estilo, IPR Gralha and BRS Pérola, while the less tolerant cultivars are: IPR Eldorado, IPR Tuiuiú, IPR Tangará, IPR Curió, UTF 3, UTF 5 and BRS Esplendor.

Keywords: *Phaseolus vulgaris*, sulfonylureas, tolerance, GGE biplot.

RESUMO - Na literatura, são poucos trabalhos que avaliam a resposta de diferentes cultivares de feijão a herbicidas, principalmente aos inibidores da enzima ALS. Os objetivos deste trabalho foram avaliar a seletividade de cultivares de feijão comum ao herbicida ethoxysulfuron e selecionar cultivares mais tolerantes ao herbicida. Um experimento foi conduzido em casa de vegetação em delineamento experimental inteiramente casualizado com quatro repetições. Os fatores foram constituídos por 20 cultivares de feijão (IPR Eldorado, IPR Siriri, IPR Gralha, IPR 81, IPR Uirapuru, IPR Colibri, IPR Tuiuiú, BRS Esplendor, IPR Tangará, IPR Juriti, IPR Corujinha, IPR Andorinha, IPR Curió, BRS Campeiro, BRS Pérola, BRS Notável, BRS Estilo, UTF 3, UTF 5 e UTF 6) e quatro doses de ethoxysulfuron (0, 50, 100 e 200 g ha^{-1}*). Na dose de 200 g* ha^{-1} *a redução da massa da parte aérea seca das plantas variou entre 30 e 80%, indicando que ocorreu elevada variabilidade na resposta dos cultivares de feijão ao herbicida. Os cultivares de feijão classificados como mais tolerantes ao ethoxysulfuron foram: IPR 81, IPR Uirapuru, BRS Estilo, IPR Gralha e BRS Pérola, enquanto os cultivares menos tolerantes foram: IPR Eldorado, IPR Tuiuiú, IPR Tangará, IPR Curió, UTF 3, UTF 5 e BRS Esplendor.*

Palavras-chave: *Phaseolus vulgaris*, sulfonilureias, tolerância, GGE biplot.

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INTRODUCTION

Ethoxysulfuron is an herbicide used to control weeds in the pre- and post-emergence of rice and sugarcane crops. This herbicide stands out for controlling infesting species of difficult management, such as those from the Cyperaceae family (Rodrigues and Almeida, 2011). On sensitive plants, the herbicide acts by inhibiting the acetolactate synthase enzyme (ALS), which is a key enzyme in the production route of the branched-chain amino acids valine, leucine and isoleucine. Ethoxysulfuron belongs to sulfonylureas, a chemical group whose herbicides stand out for their high efficiency in controlling dicotyledonous weeds. However, studies have shown that in different cultivated species, there is a different tolerance from cultivars to the same herbicide from the sulf onylurea group (Fontona et al., 2007; Cavalieri et al., 2008; Nandula et al., 2009; Procópio et al., 2009; Samtani et al., 2014), a characteristic that can compromise the grain yield in crop areas, causing losses to farmers.

Knowing the tolerance levels involving different cultivars is determinant to choose the herbicides for a crop. Studies have shown that the different tolerance level among cultivars to an herbicide can totally compromise plant development and grain yield (Soltani et al., 2010; Diesel et al., 2014). The different tolerance level among cultivars is due to the genetic variability that occurs between populations (Taran et al., 2010); thus, the importance of previous studies evaluating the response of cultivars to herbicides is emphasized. Selectivity to herbicides is considered the differential level of plant tolerance to a specific treatment; it is a relative and not absolute factor, that is, it is considered that, the bigger the tolerance difference between crop and weed, the greater the safety of the application (Oliveira Jr and Inoue, 2011).

Bean (*Phaseolus vulgaris*) is the fourth main crop cultivated in Brazil (FAOSTAT, 2016); it is cultivated in almost all regions of the country. The crop has a few latifolicidal herbicides registered for post-emergence weed control, which, associated with a rapid development cycle (<90 days), results in a narrow and limited window of weed control. This low availability is due to two main reasons: a greater sensitivity of the crop to herbicides, compared to soybean, for example, and/or to the smaller number of researches developed for this purpose.

Bean breeding programs are mainly focused on the development of cultivars with higher yield and grain quality, with little attention to herbicide tolerance. In Brazilian literature, there are few studies that demonstrate the different tolerance of bean cultivars to herbicides, especially ALS inhibiting herbicides. Recent studies have demonstrated that ethoxysulfuron is selective to bean crops (Assis et al., 2014; Pagnoncelli Jr. et al., 2016). However, as it happens to other cultivated species, it is believed that there is a different tolerance of bean cultivars to the herbicide. The objectives of this work were to evaluate the selectivity of common bean cultivars to ethoxysulfuron and to select cultivars that are more tolerant to the herbicide.

MATERIAL AND METHODS

An experiment was conducted between the summer and autumn of 2014, under greenhouse conditions. The used soil was collected in the experimental area of the University, (Universidade Tecnológica Federal do Paraná) classified as Distropherric Red Latosol, with the following physical attributes: clay, 55.7%; sand, 3%; silt, 41.3% and the chemical ones: MO, 3.35%; P_2O_5, 6.68 mg dm^{-3}; K_2O, 0.35 $cmol_c$ dm^{-3}; CTC, 12.74; pH, 5.3 and H+Al, 3.42. The soil was sieved in a 5 mm mesh sieve and deposited in plastic cups with a capacity of 500 cm^3. With the development of plants, 10 mL/cup of Hoagland solution were added weekly in order to maintain the optimal fertility for the development of the crop. The mean minimum temperature during the experimental period was around 21 ^oC, while the mean maximum temperature was approximately 31 ^oC.

The experimental design was completely randomized, in a two-factorial arrangement with four replications. The first factor consisted of 20 bean cultivars (IPR Eldorado, IPR Siriri, IPR Gralha, IPR 81, IPR Uirapuru, IPR Colibri, IPR Tuiuiú, BRS Esplendor, IPR Tangará, IPR Juriti, IPR Corujinha, IPR Andorinha, IPR Curió, BRS Campeiro, BRS Pérola, BRS Notável, BRS Estilo, UTF 3, UTF 5 and UTF 6). The second factor was composed of ethoxysulfuron doses (0, 50, 100 and 200 g ha^{-1}). In each pot five seeds were deposited; after emergence, thinning was performed, leaving only two plants per pot. Plants were watered daily, maintaining the field capacity.

The herbicide was sprayed with a CO_2 pressurized backpack sprayer, equipped with an application bar with three XR 110.02 fan-type nozzles, spaced 0.5 m apart. The used spraying volume was 200 L ha^{-1}, with an application rate of 3.6 km h^{-1}. The application occurred shortly after all plants emitted the second trifoliate leaf. The average environmental conditions during application were: relative humidity of 60% and air temperature of 28.9 °C.

Twenty-five days after application (DAA), plants were cut close to the soil and taken to a drying chamber at 60 °C, where they remained until reaching constant weight, in order to determine the Shoot Dry Matter (SDM).

Data were converted into percentage in relation to the control treatment without ethoxysulfuron application. Data were submitted to analysis of variance by F test ($p \leq 0.05$), with the aid of the RStudio program (RStudio Team, 2016), using the ExpDes.pt package (Ferreira et al., 2011). The mean data from each dose were adjusted according to the two parameter exponential decreasing model (equation 1). In addition, the standard error of the mean was calculated, in order to indicate the variability between the sample means (equation 2).

$$y = a * exp(-b * x) \quad \text{(eq. 1)}$$

where: y represents the dependent variable, x is the independent variable (herbicide dose), a is the maximum asymptote of the curve and b is the slope at the point of inflection of the curve.

$$EPM = \sigma / \sqrt{n} \quad \text{(eq. 2)}$$

where: EPM is the standard error of the mean, σ is the standard deviation and n is the number of samples.

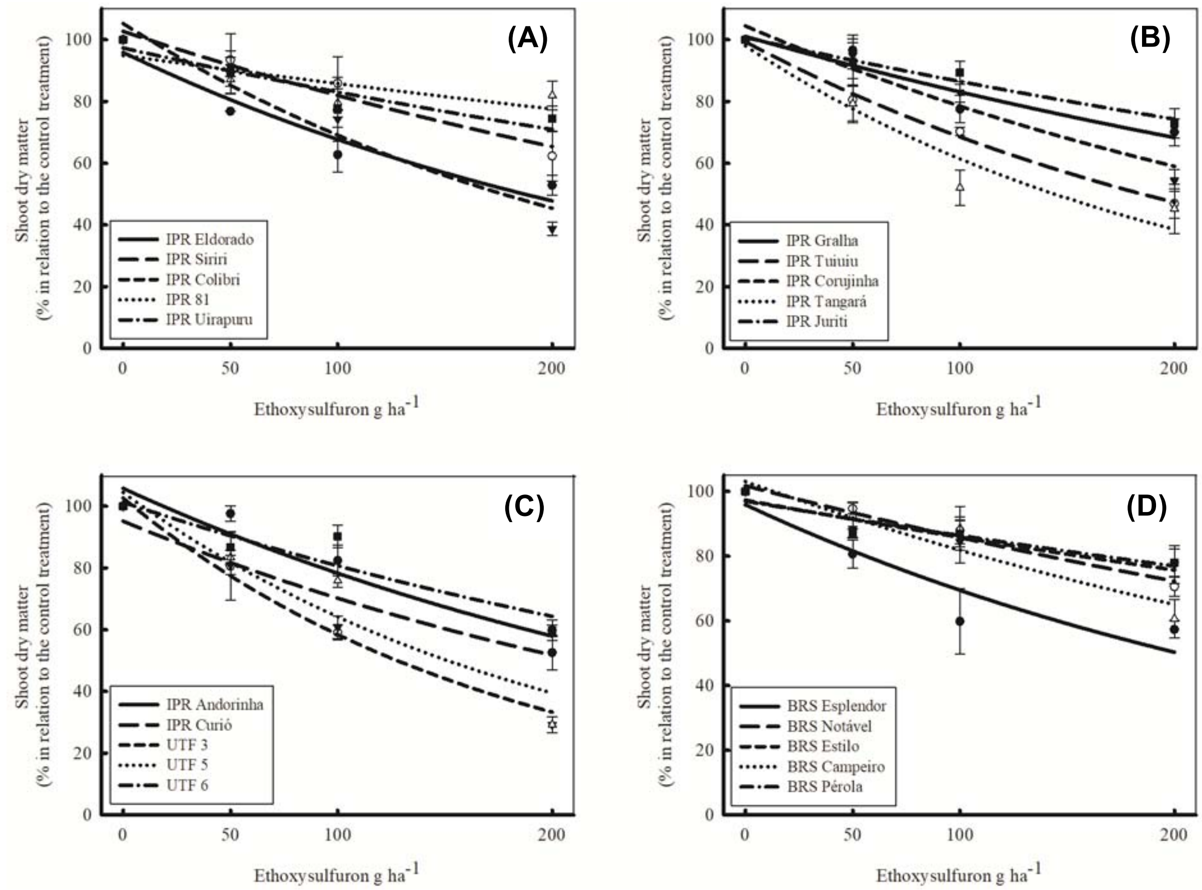
The association between dose and cultivar factors was based on the GGE Biplot model proposed by Yan et al. (2000), which considers the genotype effect and the interaction between genotype and environment (represented by herbicide doses). The associations were interpreted based on the cosine of the angle between the vectors (cultivars and doses). The association is positive when the angle between the vectors is <90°; it is negative, if >90°; and it is null if the angle between the vectors is equal to 90°. Scaled notation = 0 indicates that data have not been transformed. The Centered notation indicates the used model, where Centered = 2 represents GGE (genotype + genotype x environment interaction). SVP (singular value partitioning) is a matrix decomposition technique, where SVP = JK is suitable to compare genotypes. The analysis of the associations was performed with the RStudio software, using the GGEBiplotGUI package (Frutos et al., 2014).

RESULTADOS AND DISCUSSION

The results of the analysis of variance revealed a significant effect ($p<0.05$) for the interaction between cultivars x doses (data not shown), indicating that cultivars responded differently to increasing herbicide doses.

A high variability was observed in the response of bean cultivars to ethoxysulfuron (Figure 1 and Table 1). Regardless of the cultivar, the SDM of plants was reduced with increasing herbicide doses. The SDM of cultivars UTF 3 and UTF 5, treated with the highest herbicide dose (200 g ha^{-1}), was reduced to approximately 30% of the control treatment, whereas cultivars IPR 81, BRS Estilo and BRS Pérola were reduced to approximately 80% of the control treatment, standing out for the largest and smallest SDM reductions, respectively. At the 100 ha^{-1} dose, which is recommended for weed control in rice and sugarcane (Rodrigues and Almeida, 2011), 10 cultivars maintained their SDM reduction above 80% (IPR Siriri, IPR 81, IPR Corujinha, IPR Juriti, IPR Andorinha, UTF 6, BRS Notável, BRS Estilo, BRS Campeiro and BRS Pérola), while at the 50 g ha^{-1} dose, except for IPR Eldorado and IPR Tangará, all cultivars maintained their SDM reduction above 80%.

The association between cultivar and dose factors indicates the performance of each cultivar at each dose; the stronger the positive association (the lower the angle between the vectors) between cultivar and dose, the higher the cultivar performance at a certain dose. Cultivars IPR Eldorado, IPR Colibri, IPR Tuiuiú, IPR Tangará, Curi, IPR Curió, UTF 3, UTF 5 and BRS Esplendor



The dots represent the mean values of four replications, and the vertical bars correspond to their standard error.

Figure 1 - Shoot dry matter (%) of 20 bean cultivars according to different doses of ethoxysulfuron.

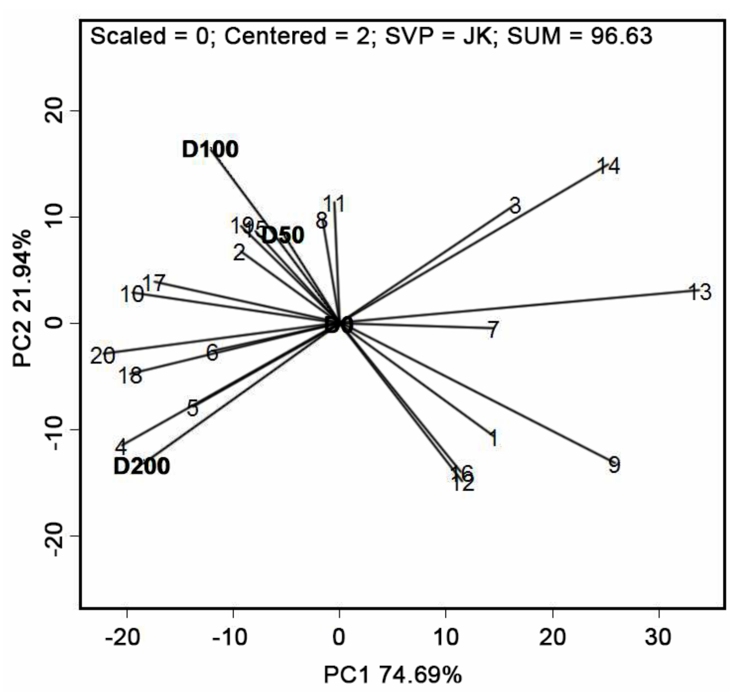
presented negative associations at all tested doses (angle>90º) (Figure 2). As observed in Figure 1, the SDM reduction of these cultivars was higher than the others even at the dose of 50 g ha^{-1}; moreover, they are among the ones presenting greater curve slope (between 0.003 and 0.006) (Table 1). Therefore, among the evaluated cultivars, these can be classified as less tolerant to ethoxysulfuron. The others had a positive association (angle<90º) with at least one of the tested doses. In order of greatest association, cultivars IPR 81, IPR Uirapuru, BRS Estilo, Gralha IPR and BRS Pérola were the most associated with the 200 g ha^{-1} dose. According to Figure 1, these cultivars showed lower SDM reduction at 200 g ha^{-1}, and, according to Table 1, they were among the ones presenting the lowest slope of the curve (0.001 to 0.002). Together, these results allow inferring that these cultivars have higher tolerance to ethoxysulfuron than the others. Evaluating the tolerance of several bean cultivars to different herbicides, Procópio et al. (2009) found that BRS Pérola has a high tolerance to herbicides from the chlorimuron-ethyl sulfonylurea group. Cultivars IPR Siriri, BRS Campeiro, UTF 6, IPR Corujinha and IPR Andorinha showed strong association only with 50 and 100 g ha^{-1} doses; therefore, the tolerance level of these materials can be classified as intermediate, in relation to the others.

Plant tolerance to herbicides involves several mechanisms. In cultivated plants, the metabolization of the herbicide molecule by specific enzymes, such as P450 mono-oxygenases and Glutathione-S-Transferase (Werck-Reichhart et al., 2000; Powles and Yu, 2010) stands out. Previous studies have shown that the main mechanism involved in bean tolerance to ethoxysulfuron is the metabolization of the herbicide molecule (Pagnoncelli Jr. et al., 2016). Overall data corroborate the hypothesis that bean cultivars have a differential capacity to metabolize ethoxysulfuron. In addition to metabolization, absorption and translocation can directly influence herbicide tolerance (Barnes and Oliver, 2004; Rojano-Delgado et al., 2011; Bukun et al., 2012). Studies with different cultivated species indicate that absorption, translocation

Table 1 - Parameters of the equation, determination coefficient (R^2), mean squared error (MSE) and probability of the equation (*p*), for the shoot dry matter (%) of 20 bean cultivars after the application of ethoxysulfuron

Cultivar	Parameter [1]		R^2	MSE	*p*
	a	*b*			
IPR Eldorado	95.91 (5.44)[2]**	0.003 (0.0007)*	0.90	40.32	<0.05
IPR Siriri	102.70 (3.49)**	0.002 (0.0004)*	0.93	17.67	<0.05
IPR Colibri	105.25 (7.10)**	0.004 (0.0009)*	0.90	66.49	<0.05
IPR 81	94.94 (5.46)**	0.001 (0.0005)^{ns}	0.44	46.64	0.21
IPR Uirapuru	97.31 (4.13)**	0.002 (0.0004)^{ns}	0.81	25.80	0.06
IPR Gralha	101.07 (4.50)**	0.002 (0.0005)*	0.86	29.89	0.05
IPR Tuiuiu	99.34 (1.66)**	0.004 (0.0002)**	0.99	3.72	<0.05
IPR Corujinha	104.46 (5.32)**	0.003 (0.0006)*	0.90	39.83	<0.05
IPR Tangará	98.02 (7.37)**	0.005 (0.001)*	0.89	70.23	<0.05
IPR Juriti	100.72 (1.93)**	0.001 (0.0002)*	0.96	5.65	<0.05
IPR Andorinha	105.78 (6.62)**	0.003 (0.0007)*	0.87	61.24	<0.05
IPR Curió	95.16 (8.73)**	0.003 (0.001)^{ns}	0.72	106.19	0.1
UTF 3	102.64 (4.09)**	0.006 (0.0006)*	0.98	20.75	<0.05
UTF 5	104.46 (10.14)**	0.005 (0.001)^{ns}	0.86	131.60	0.05
UTF 6	101.28 (6.65)**	0.002 (0.0007)^{ns}	0.78	64.25	0.07
BRS Esplendor	95.92 (7.59)**	0.003 (0.0009)^{ns}	0.80	79.60	0.07
BRS Notável	101.80 (2.02)**	0.002 (0.0002)*	0.96	6.15	<0.05
BRS Estilo	97.35 (2.55)**	0.001 (0.0003)*	0.88	10.05	<0.05
BRS Campeiro	103.10 (5.07)**	0.002 (0.0005)*	0.87	37.32	<0.05
BRS Pérola	97.03 (3.17)**	0.001 (0.0003)^{ns}	0.81	15.56	0.06

[1] Decreasing exponential of two parameters; [2] Values in parentheses indicate the standard error; * and ** significant at 1 and 5% of error probability, respectively; ns = not significant.



D0 = 0 g ha^{-1}; D50 = 50 g ha^{-1}; D100 = 100 g ha^{-1} and D200 = 200 g ha^{-1}. 1 = IPR Eldorado, 2 = IPR Siriri, 3 = IPR Colibri, 4 = IPR 81, 5 = IPR Uirapuru, 6 = IPR Gralha, 7 = IPR Tuiuiú, 8 = IPR Corujinha, 9 = IPR Tangará, 10 = IPR Juriti, 11 = IPR Andorinha, 12 = IPR Curió, 13 = UTF 3, 14 = UTF 5, 15 = UTF 6, 16 = BRS Esplendor, 17 = BRS Notável, 18 = BRS Estilo, 19 = BRS Campeiro, 20 = BRS Pérola.

Figure 2 - Plotting of the principal component scores (PC), according to the GGE biplot model, as for the association between 20 bean cultivars and four doses of ethoxysulfuron.

and differential metabolism provide distinct tolerance levels to different herbicides (Connelly et al., 1988; Rojano-Delgado et al., 2015). Knowing the tolerance of different cultivars to herbicides is an important information, which helps in the breeding programs directed to the development of more tolerant cultivars, thus reducing agricultural losses due to the application of doses that are not supported by plants.

Results demonstrate that the analysis of the association between factors of the GGE Biplot model can be used together with the non-linear regression analysis of two parameters, helping to identify more tolerant herbicide cultivars. These analyses are complementary to each other because, while the regression analysis indicates the overall performance of the genotype at all doses, the association analysis indicates the performance of each cultivar at each dose, facilitating the understanding of the effects.

It was observed that there is a differential tolerance of bean cultivars to ethoxysulfuron, and that the herbicide presents high selectivity to some cultivars when the application is carried out during post-emergence. Bean cultivars that were classified as more tolerant to ethoxysulfuron were: IPR 81, IPR Uirapuru, BRS Estilo, IPR Gralha and BRS Pérola, while the less tolerant cultivars were: IPR Eldorado, IPR Colibri, IPR Tuiuiú, IPR Tangará, IPR Curió, UTF 3, UTF 5 and BRS Splendor.

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