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Management of resistant biotypes of *Eleusine indica* and glyphosate-tolerant *Spermacocea latifolia with pre-emergent herbicides associated with sequential application of desiccants*

Manejo de biótipos resistentes de Eleusine indica e de Spermacocea latifolia tolerante ao glyphosate com herbicidas pré-emergentes associados à aplicação sequencial de dessecantes

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ABSTRACT

It has been difficult to control *Eleusine indica* (L.) Gaertn and *Spermacocea latifolia* Aubl. in cotton and soybean crops due to their herbicide resistance or tolerance to glyphosate. Thus, this study's objective was to evaluate the herbicide efficacy applied in pre-emergence, associated with desiccant herbicide in sequential application, in these species. The experiments for *S. latifolia* and *E. indica* were conducted separately in a greenhouse. The experimental design was completely randomized, with 4 replications, in a 6 x 3 factorial. The first factor consisted of pre-emerging herbicides applied two days after the sowing of each species, diclosulam (35 g a.i./ha), s-metolachlor (600 g a.i./ha), pyroxasulfone (200 g a.i./ha) + flumioxazin (200 g a.i./ha), diuron (2000 g a.i./ha), trifluralin (600 g a.i./ha), and the treatment without herbicide. The second factor consisted of the application of diquat (200 g a.i./ha), ammonium glufosinate (400 g a.i./ha), or the absence of sequential application. The results revealed that only for the diclosulam herbicide a sequential application with desiccants was necessary for an effective control of *E. indica*. The other herbicide applied in pre-emergence showed high efficacy (> 90%) in *E. indica* control when applied individually. Regarding *S. latifolia* chemical control, the herbicides s-metolachlor (80.04%), pyroxasulfone + flumioxazin (100%), diclosulam (82.08%) and diuron (89.58%), applied in pre-emergence, presented a satisfactory control at 42 days after emergence. The sequential applications promoted better control of *S. latifolia* to trifluralin and diuron. In conclusion, there are pre-emergence options for the effective control of *E. indica* and *S. latifolia*. However, sequential application can be an important tool for improving the control of some weed species, such as those studied in this work, by certain herbicides.

KEYWORDS: goosegrass; buttonweed; chemical control; management; resistance; tolerance.

RESUMO

A resistência ou tolerância ao herbicida glyphosate de *Eleusine indica* (L.) Gaertn and *Spermacocea latifolia* Aubl. nos cultivos de algodão e soja tem dificultado o controle dessas espécies nessas culturas. Desse modo, o objetivo deste trabalho foi avaliar a eficácia de herbicidas aplicados em pré- emergência associados a herbicidas dessecantes em aplicação sequencial no controle destas espécies. Os experimentos foram realizados em casa-de-vegetação separadamente para *S. latifolia* e *E. indica*. O delineamento experimental foi inteiramente casualizado, com 4 repetições, em esquema fatorial 6 x 3, sendo o primeiro fator constituído por herbicidas pré-emergentes aplicados dois dias após a semeadura de cada espécie: diclosulam (35 g i.a. ha^{-1}), s-metalochlor (600 g i.a. ha^{-1}), piroxasulfona (200 g i.a. ha^{-1}) + flumioxazina (200 g i.a. ha^{-1}), diuron (2000 g i.a. ha^{-1}), trifluralina (600 g i.a. ha^{-1}), mais o tratamento sem herbicida. O segundo fator foi composto pela aplicação dos dessecantes diquat (200 g i.a. ha^{-1}), glufosinato de amônio (400 g i.a. ha^{-1}) ou ausência de aplicação sequencial. Os resultados evidenciaram que para o controle eficaz de *E. indica*, seria necessária a aplicação sequencial com dessecantes apenas para o herbicida diclosulam. Os demais herbicidas aplicados em pré-emergência apresentaram elevada eficácia no controle de *E. indica* de forma isolada (>90%). Para o controle químico de *S. latifolia* os herbicidas s-metolachor (80,04%), pyroxasulfone + flumioxazin (100%), diclosulam (82,08%) e diuron (89,58%), aplicados em pré-emergência apresentaram controle satisfatório na avaliação aos 42 dias após emergência. As aplicações sequenciais promoveram melhor controle de *S. latifolia* para diuron e trifluralina. Conclui-se que há opções de herbicidas pré-emergentes para o controle efetivo de *E. indica* e *S. latifolia*, todavia a aplicação sequencial é uma ferramenta importante para incrementar o controle das espécies por alguns herbicidas.

PALAVRAS-CHAVE: Capim-pé-de-galinha; erva-quente; controle químico; manejo; resistência; tolerância.

INTRODUCTION

It is common in intensive agricultural systems to use only herbicides for weed management, ignoring other possible control methods (GUIMARÃES et al. 2007). Within the available herbicide options, glyphosate stands out and presents high effectiveness in broad leaves and grasses weed control. However, the exclusive use of glyphosate, primarily due to the adoption of genetically modified cotton and soybeans, resulted in resistant biotypes or tolerant species selection, which compromises the herbicide's effectiveness (CAVALIERI et al. 2022).

In Brazil, 20 weed biotypes have been reported to be resistant to glyphosate, either with a single resistance or multiple resistances. *Eleusine indica* is within these biotypes, and in some cases is reported to be resistant to Acetyl-CoA carboxylase inhibitors (ACCase) in 2003, 5-enolpyruvylshikimate-3-phosphate (EPSP) inhibitors in 2016, and multiple resistances to other two action mechanisms in 2017 (HEAP 2023).

E. indica is an annual grass that belongs to the Poaceae family. It has a C4 photosynthetic metabolism and is cosmopolitan and not very demanding regarding soil type, tolerating a wide range of pH levels. However, it is highly competitive, and adapts to almost all regions of the world, producing up to 140 thousand seeds per plant. Additionally, it can be host to insects, fungi, viruses, and nematodes harmful to crops (RADOSEVICH et al. 2007, BOLDRINI et al. 2008, CARNEIRO & IRGANG 2005). In the world, biotypes of *E. indica* resistant to herbicides with the following mechanisms of action have been detected: microtubule formation inhibitors (1973), ALS inhibitors (1989), ACCase inhibitors (1990), photosystem I inhibitors (1990), EPSPS inhibitors (1997), photosystem II inhibitors (2003), glutamine synthetase inhibitors (2009) and protoporphyrinogen oxidase (PPO) inhibitors (2015) (HEAP 2023).

The *Spermacoce latifolia* is native to Brazil and can be found in the South, Southeast, Central-West, and North regions. It is an annual plant from the Rubiaceae family and has prostrate and ascending growth habits. The stem has a cylindrical base, with quadrilateral branches that are either glabrous or puberulous, with sessile leaves or short petioles. Connected to the stem, the white-colored corolla inflorescence may reach up to 50 centimeters, and it uses seed for reproduction. The species adapts easily to acidic, low-fertility soils. However, its development is better in high-fertility soils. According to LORENZI (2006), this species prefers acidic soils and demonstrates a certain shade tolerance. Adequate soil management, soil acidity correction, and good fertility levels contribute to decreasing its infestation.

Successive applications of glyphosate can select this species in the field (PROCÓPIO et al. 2007). Doses of glyphosate - 720 and 1080 g/ha were ineffective in their control, on the other hand, the alternative control, using the herbicide 2,4-D (670 g/ha), provided satisfactory control (BARROS 2001). The low effectiveness of glyphosate in controlling *S. latifolia* in fields with crops resistant to this herbicide has led the management to combine other herbicides, to achieve satisfactory control (EUBANK et al. 2008, GALON et al. 2013, KALSING et al. 2020).

FADIN et al. (2018) reported that *S. verticillata*, another Spermacocea species, presents low glyphosate translocation to the root when it is in the flowering stage. They verified that the glyphosate application during the initial stages of the species development can be effective, as well as the application of paraquat, flumioxazin, and glyphosate and flumioxazin or cloransulam mixtures. On the other hand, late applications may result in deficient control, mainly when glyphosate is used. Therefore, early applications may assist in the management of this species.

The combination of pre-emergent herbicides associated or in sequence with post-emergent may be an effective alternative in weed control (SCROGGS et al. 2007, RAIMONDI et al. 2012).

In this context, it is essential to develop management strategies that combine the use of herbicides with different mechanisms of action applied at different stages of plant development, in order to achieve the closure of crops in the clean. Therefore, the objective of this study was to evaluate the control of species *Eleusine indica* and *Spermacoce latifolia* with herbicides applied in pre-emergence associated or no with desiccant herbicides in sequential application.

MATERIAL AND METHODS

The experiment was carried out in a greenhouse at the Federal University of São Carlos, Araras campus. The seeds of *S. latifolia* and *E. indica* was from the Agrocosmos company, which is specialized in the production of weed seeds. The *E. indica* seeds came from glyphosate-resistant biotypes, while the *S. latifolia* species is tolerant to the same herbicide. Each experimental unit consisted of a 5L volumetric capacity pot, filled with soil samples from a dark red Oxisol (clayey texture), whose chemical analysis was performed by the Laboratory of Chemistry and Soil Fertility of CCA/UFSCar. The results of the chemical analysis of the soil (0-20cm) were: P(resin) - 15 mg/dm^3; O.M - 38 g/m^3; pH $CaCl_2$ - 5.6; K, Ca, Mg, H+Al, SB, CEC – 5.4, 53, 13, 26, 71.4, 97.4 respectively and V% - 73.

According to Agrocosmos, the viability of *E. indica* seeds was 60% and *S. latifolia* 50%, so we sowed each species separately with the amount of seeds needed to have at least 5 plants per pot. The pots were kept in a greenhouse with automatic irrigation. The experimental design was completely randomized, with 4 replicates, in a 6 × 3 factorial scheme. The first factor consisted of 6 treatments applied in pre-emergence, two days after the sowing (diclosulam, s-metolachlor, pyroxasulfone + flumioxazin, diuron, and trifluralin, and without herbicide). The second factor was sequentially applied desiccant herbicides (diquat, ammonium glufosinate, and without sequential application). Desiccants were applied when the *S. latifolia* featured two pairs of fully expanded leaves and *E. indica* four leaves (BBCH scale 14), 42 days after the application of pre-emergent herbicides. Desiccants herbicides were applied to treatments with pre-emergent herbicides that achieved less than 100% control in the last evaluation.

Table 1 shows the treatments and doses used in the trial. The herbicides were applied with a CO_2 air pressurized knapsack sprayer, equipped with four flat fan TeeJet 110.02 spray nozzles with 0.5m spacing. The application was carried out with 0.5m spacing from the target. A spray volume of 200 L/ha and a pressure of 40 Psi were used.

Table 1. Relationship of treatments applied in pre-emergence and management of sequential application of desiccants for *Spermacoce latifolia and Eleusine indica* control.

Factor 1 - Pre-emergence	Dose g a.i./ha	Factor 2 - Sequential in post-emergence	Dose g a.i./ha
Diclosulam	35	Without sequential	-
Diclosulam	35	Diquat	200
Diclosulam	35	Ammonium glufosinate	400
S-metolachlor	600	Without sequential	-
S-metolachlor	600	Diquat	200
S-metolachlor	600	Ammonium glufosinate	400
Piroxasulfone + flumioxazin	200 + 200	Without sequential	-
Piroxasulfone + flumioxazin	200 + 200	Diquat	200
Piroxasulfone + flumioxazin	200 + 200	Ammonium glufosinate	400
Diuron	2000	Without sequential	-
Diuron	2000	Diquat	200
Diuron	2000	Ammonium glufosinate	400
Trifluralin	600	Without sequential	-
Trifluralin	600	Diquat	200
Trifluralin	600	Ammonium glufosinate	400
Control	-	Without sequential	-
Control	-	Diquat	200
Control	-	Ammonium glufosinate	400

The evaluation of weed control was conducted based on the visual criterion of plant injury, which ranges from 0 to 100% (ALAM 1974). A rating of 0% indicates the absence of visible symptoms, while a rating of 100% represents complete plant mortality. Treatment evaluations were performed at 14, 21, 28, 35, and 42 days after emergence (DAE). At 42 DAE the plants reached the appropriate phenological stage for sequential application, and after application, they were evaluated at 7, 14, and 21 days after sequential application (DAS). At 21 DAS, the plants were cut at ground level, and their biomass was dried in a forced air circulation oven at 60°C for 72 hours. Subsequently, the dried biomass was weighed to determine the dry biomass mass. The percentage (%) of the dry mass of the treatments was determined concerning the control without herbicide application (0 g a.i./ha), according to the following formula:

$$X\ (\%) = 100 - \left[\left(\frac{m\ rep\ trat\ x\ 100}{m\ \bar{x}\ test}\right)\right] (1)$$

Where,
X= percentage reduction of treatment;
m = mass (g);
trat= treatment;
$\overline{X}$ = mean;
Test = control.

The data were subjected to analysis of variance using the F test, using the Scott-Knott Test at a level of 5% (p≤0.05) to compare treatment means. The percentage data of phytoxicity were transformed into arcsine √x/100 to find a basic hypothesis for applying ANOVA (analysis of variances), but the data presented in the results tables are original (LITTLE & HILLS 1972).

RESULTS

The results obtained from the evaluations of pre-emergent herbicides' control on *E. indica* influenced by the evaluation periods are presented in Table 2. There was a significant interaction between the factors.

Table 2. Percentage of *Eleusine indica* control under the effect of herbicides applied in pre-emergence, evaluated at 14, 28, and 42 days after the emergence of the control, before sequential application.

Control of *E. indica* before sequential application (%)						
Herbicides in pre-emergence	14 DAE		28 DAE		42 DAE	
Diclosulam	60.83	bC	67.33	bB	74.58	bA
S-metolachlor	90.16	aA	95.58	aA	95.33	aA
Piroxasulfone+flumioxazin	90.00	aA	90.00	aA	95.00	aA
Diuron	99.16	aA	100.00	aA	100.00	aA
Trifluralin	98.33	aA	97.50	aA	95.83	aA
Control	0.00	cA	0.00	cA	0.00	cA
CV (%)			9.11			
$F(A)=1155.19^{**}$; $F(B)=1.28^{NS}$; $F(AxB)=2.14^{*}$						

* CV (%): coefficient of variation; Factor A: pre-emergent and control herbicides; Factor B: evaluation period. ** significant and ^{NS} non-significant at 5% probability level by F-test. Means followed by the same letter, lowercase in the column and uppercase in the row, do not differ significantly from each other according to the Scott-Knott test at a 5% significance level (p≤ 0,05).

Regardless of the evaluation period, the herbicides s-metolachlor, pyroxasulfone + flumioxazin, diuron, and trifluralin provided efficient control (>90%) of *E. indica*. Diclosulam showed an increase in plant control throughout the evaluation period, however, the control was less than 80%.

Table 3 shows the results of the association of pre-emergent herbicides with the sequential application of desiccants. There was significant interaction between pre-emergent and post-emergent herbicides applied sequentially. Regardless of the evaluation period (7, 14, or 21 DAS), the herbicides s-metolachlor, pyroxasulfone + flumioxazin, diuron, and trifluralin provided high control means (>95%) of *E. indica.* However, for diclosulam, there was an increase in control (97%) with sequential applications of ammonium glufosinate or diquat compared to its isolated use (70%). Diquat in an isolated application, without the use of pre-emergent herbicide, presented 80% control, while glufosinate ammonium promoted 100% control from the 14 DAS.

The results obtained for the reduction of shoot dry mass in *E. indica* compared to the control, evaluated at 21 DAS, are presented in Table 4. There was significant interaction between pre-emergent herbicides and sequential application.

Table 3. Percentage of *Eleusina indica* control, evaluated at 7, 14, and 21 days after sequential application of desiccant herbicides, after management with pre-emergent herbicides.

Control *E. indica* 7 DAS (%) (49 days after application of pre-emergent herbicides)						
	Sequential Application					
Herbicides in pre-emergence	Without		Diquat		GA 400	
Diclosulam	66.25	bB	97.50	aA	98.75	aA
S-metolachlor	95.50	aA	100.00	aA	100.00	aA
Piroxasulfone+flumioxazin	100.00	aA	100.00	aA	100.00	aA
Diuron	100.00	aA	100.00	aA	100.00	aA
Trifluralin	100.00	aA	97.50	aA	100.00	aA
Control	0.00	cC	70.00	bB	90.00	bA
CV (%)	5.73					
F(A)=890.23**; F(B)=11.44**; F(AxB)=10.47**						
Control *E. indica* 14 DAS (%) (56 days after application of pre-emergent herbicides)						
	Sequential Application					
Herbicides in pre-emergence	Without		Diquat		GA 400	
Diclosulam	67.50	bB	98.25	aA	98.75	aA
S-metolachlor	97.50	aA	100.00	aA	100.00	aA
Piroxasulfone+flumioxazin	100.00	aA	100.00	aA	100.00	aA
Diuron	100.00	aA	100.00	aA	100.00	aA
Trifluralin	100.00	aA	97.50	aA	100.00	aA
Control	0.00	cC	80.00	bB	100.00	aA
CV (%)	6.07					
F(A)=790.59**; F(B)=9.59**; F(AxB)=8.78**						
Control *E. indica* 21 DAS (%) (63 days after application of pre-emergent herbicides)						
	Sequential Application					
Herbicides in pre-emergence	Without		Diquat		GA 400	
Diclosulam	70.00	bB	96,25	aA	100.00	aA
S-metolachlor	97.50	aA	100.00	aA	100.00	aA
Piroxasulfone+flumioxazin	100.00	aA	100.00	aA	100.00	aA
Diuron	100.00	aA	100.00	aA	100.00	aA
Trifluralin	100.00	aA	100.00	aA	100.00	aA
Control	0.00	cC	80.00	bB	100.00	aA
CV (%)	4.56					
F(A)=1399.85**;F(B)=15.90**; F(AxB)=12.58**						

*GA: glufosinate ammonium; CV (%): coefficient of variation; Factor A: pre-emergent and control herbicides; Factor B: sequential application. ** significant at 5% probability level by F-test. Means followed by the same letter, lowercase in the column and uppercase in the row, do not differ significantly from each other according to the Scott-Knott test at a 5% significance level ($p \leq 0,05$).

The dry mass results followed a similar trend to the control percentages. Apart from diclosulam, the pre-emergent herbicides did not differ concerning the reduction of the dry mass of *E. indica* compared to the sequential application of diquat or ammonium glufosinate. There was a reduction of 100% of the dry mass with sequential applications and at least 93.87% in isolated applications. For diclosulam, the reduction remained at 82.85% when post-emergent herbicides were not applied. However, with sequential application, the control of the species reached 100%.

Table 4. Reduction of shoot dry mass of *Eleusine indica* regarding the control, evaluated at 21 after the sequential application of desiccant herbicides, after the management with pre-emergent herbicides.

Reduction of shoot dry mass (%) of *E. indica 21 DAS*						
63 days after application of pre-emergent herbicides)						
Herbicides in pre-emergence	Without		Diquat		GA 400	
Diclosulam	82.85	bB	100.00	aA	100.00	aA
S-metalachor	93.87	aA	100.00	aA	100.00	aA
Piroxasulfone+flumioxazin	100.00	aA	100.00	aA	100.00	aA
Diuron	100.00	aA	100.00	aA	100.00	aA
Trifluralin	100.00	aA	100.00	aA	100.00	aA
Control	0.00	cC	70.00	bB	100.00	aA
CV (%)			15.60			
F(A)=130.19**; F(B)=6.65**; F(AxB)=7.10**						

*GA: glufosinate ammonium; CV (%): coefficient of variation; Factor A: pre-emergent and control herbicides; Factor B: sequential application. ** significant at 5% probability level by F-test. Means followed by the same letter, lowercase in the column and uppercase in the row, do not differ significantly from each other according to the Scott-Knott test at a 5% significance level (p ≤ 0,05).

For *S. latifolia*, the isolated results of the pre-emergence application are presented in Table 5. There was a significant interaction between herbicides and evaluation periods. Diclosulam, pyroxasulfone + flumioxazin, and diuron were effective (>80%) in controlling *S. latifolia* at all evaluation periods. However, for diclosulam, there was a control reduction during the evaluation periods, and the opposite was observed for diuron and s-metolachlor. Regarding trifluralin, this herbicide was not efficient for the management of the species, with a maximum control of 52.5%. In the evaluation at 14 DAE, the herbicide s-metolachlor was not efficient in controlling the weed species (40%).

Table 5. Percentage of *Spermacocea latifolia* control under the effect of herbicides applied in pre-emergence, evaluated at 14, 28 and 42 days after emergence of the control before sequential application.

Control of *S. latifolia* before sequential application (%)						
Herbicides in pre-emergence	14 DAE		28 DAE		42 DAE	
Diclosulam	84.16	bA	89.58	aA	82.08	bB
S-metalachor	40.00	cB	80.58	bA	80.04	bA
Piroxasulfone+flumioxazin	100.00	aA	100.00	aA	100.00	aA
Diuron	80.83	bB	82.50	bA	89.58	aA
Trifluralin	52.50	cA	50.83	cA	52.50	cA
Control	0.00	dA	0.00	dA	0.00	dA
CV (%)			16.12			
F(A)=390.30**; F(B)=0.30^{NS}; F(AxB)=1.97*						

* CV (%): coefficient of variation; Factor A: pre-emergent and control herbicides; Factor B: evaluation period. ** significant and ^{NS} non-significant at 5% probability level by F-test. Means followed by the same letter, lowercase in the column and uppercase in the row, do not differ significantly from each other according to the Scott-Knott test at a 5% significance level (p≤ 0,05).

The results of the control evaluations of *S. latifolia* at 7, 14, and 21 DAS can be found in Table 6. There was a significant interaction between the factors evaluated regardless of the evaluation period.

In general, the applications of pre-emergent herbicides resulted in control means above 80% in all evaluation periods, with or without sequential application of diquat or glufosinate ammonium herbicides. However, the herbicides diclosulam, diuron, and trifluralin presented statistically lower control than s-metolachlor and pyroxasulfone+flumioxazin applied in pre-emergence. It is important to emphasize that these evaluations occurred at 49, 56, and 63 days after the application of the pre-emergent herbicides, therefore, it can still be considered a satisfactory control.

Table 6. Percentage of *Spermacocea latifolia* control, evaluated at 7, 14 and 21 days after sequential application of desiccant herbicides, after management with pre-emergent herbicides.

Control *S. latifolia* 7 DAS (%) (49 days after application of pre-emergent herbicides)						
	Sequential Application					
Herbicides in pre-emergence	Without		Diquat		GA 400	
Diclosulam	83.75	bB	96.25	aA	98.75	aA
S-metolachlor	90.00	aA	100.00	aA	100.00	aA
Piroxasulfone+flumioxazin	100.00	aA	100.00	aA	100.00	aA
Diuron	87.50	bB	100.00	aA	97.50	aA
Trifluralin	57.50	cB	96.25	aA	96.25	aA
Control	0.00	dC	60.00	bB	80.00	bA
CV (%)	4.01					
F(A)=1791.80**;F(B)=11.90**; F(AxB)=3.36**						
Control *S. latifolia* 14 DAS (%) (56 days after application of pre-emergent herbicides)						
	Sequential Application					
Herbicides in pre-emergence	Without		Diquat		GA 400	
Diclosulam	83.75	bB	96.25	bA	98.75	aA
S-metolachlor	100.00	aA	100.00	aA	100.00	aA
Piroxasulfone+flumioxazin	100.00	aA	100.00	aA	100.00	aA
Diuron	87.50	bB	100.00	aA	100.00	aA
Trifluralin	55.00	cC	93.75	bB	100.00	aA
Control	0.00	dC	65.00	cB	80.00	bA
CV (%)	3.80					
F(A)=1949.71**;F(B)=16.32**; F(AxB)=4.75**						
Control *S. latifolia* 21 DAS (%) (63 days after application of pre-emergent herbicides)						
	Sequential Application					
Herbicides in pre-emergence	Without		Diquat		GA 400	
Diclosulam	87.00	bA	98.50	aA	100.00	aA
S-metolachlor	100.00	aA	100.00	aA	100.00	aA
Piroxasulfone+flumioxazin	100.00	aA	100.00	aA	100.00	aA
Diuron	85.00	bB	100.00	aA	100.00	aA
Trifluralin	83.75	bC	93.75	bB	100.00	aA
Control	0.00	cB	70.00	cA	85.00	bA
CV (%)	4.47					
F(A)=1448.28**;F(B)=16.39**; F(AxB)=5.53**						

*GA: glufosinate ammonium; CV (%): coefficient of variation; Factor A: pre-emergent and control herbicides; Factor B: sequential application.** significant at 5% probability level by F-test. Means followed by the same letter, lowercase in the column and uppercase in the row, do not differ significantly from each other according to the Scott-Knott test at a 5% significance level (p≤ 0,05).

Regarding the sequential application, for the herbicides trifluralin and diuron, there was an increase in control. Whereas for trifluralin, the ammonium glufosinate presented a higher percentage of control (100%) than diquat (93.75%).

The results of the dry mass of *S. latifolia* are found in Table 7. Diuron herbicide showed lower performance than other pre-emergent herbicides. Among the herbicides applied sequentially in isolation, ammonium glufosinate showed better performance in controlling the species (80%) compared to diquat

(60%).

Table 7. Reduction of shoot dry mass of *Spermacocea latifolia* compared to the control, evaluated at 21 days after the sequential application of desiccant herbicides, after management with pre-emergent herbicides.

Reduction of shoot dry mass (%) of *S. latifolia 21 DAS*						
63 days after application of pre-emergent herbicides)						
Herbicides in pre-emergence	Without		Diquat		GA 400	
Diclosulam	95.30	aA	99.43	aA	100.00	aA
S-metalachor	100.00	aA	100.00	aA	100.00	aA
Piroxasulfone+flumioxazin	100.00	aA	100.00	aA	100.00	aA
Diuron	72.02	bB	100.00	aA	100.00	aA
Trifluralin	95.27	aA	98.36	aA	100.00	aA
Control	0.00	cC	60.00	bB	80.00	bA
CV (%)			13.99			
F(A)=148.25**; F(B)=1.91^{NS}; F(AxB)=1.27^{NS}						

*GA: glufosinate ammonium; CV (%): coefficient of variation; Factor A: pre-emergent and control herbicides; Factor B: sequential application. ** significant and NS non-significant at 5% probability level by F-test. Means followed by the same letter, lowercase in the column and uppercase in the row, do not differ significantly from each other according to the Scott-Knott test at a 5% significance level (p ≤ 0,05).

DISCUSSION

The intensive used of herbicide alone has resulted in the evolution of *E. indica* resistance to various groups of herbicides such as paraquat, imidazolinones, glyphosate, metribuzin, glufosinate, aryloxyphenoxyproprionates, and cyclohexane (HEAP 2023). In order to slow down or reduce the evolution of herbicide resistance cases, multiple tactics should be employed to reduce selection pressure of the herbicide as well as associating the use of pre-emergence herbicides with post-emergence herbicides of different mechanisms of action.

The outcomes about *E. indica* control are consistent with the ones reported by ROSA (2016), who observed control above 85% in different populations of *E. indica* at 30 to 120 days after the application of s-metolachlor and trifluralin. Likewise, TAKANO et al. (2018) observed that the herbicides s-metolachlor, sulfentrazone, and trifluralin provided control levels above 90% in populations of *E. indica* resistant to glyphosate.

Regardless of the evaluation period in this experiment the herbicides s-metolachlor, pyroxasulfone + flumioxazin, diuron, and trifluralin provided high control of *E. indica*, which made sequential applications not necessary. However, for diclosulam, there was an increase in control with sequential applications of ammonium glufosinate or diquat compared to its isolated use. These data are in accordance with those obtained by SILVA (2020), who verified that the dose of 29.4 g a.i./ha of diclosulam showed control of less than 70% of *E. indica* in different places.

In this study, the ammonium glufosinate proved to be a great control tool for *E. indica*. However, in adult plants, low efficacy of ammonium glufosinate on *E. indica* has been reported (CULPEPPER et al. 2000). TAKANO et al. (2018) observed that the maximum control provided by ammonium-glufosinate (490 g ha^{-1}) was 60% over plants with 4-8 leaves.

A sequential application would not be necessary to increase the control of *E. indica*, showing that the other pre-emergent options, except for diclosulam, were extremely effective in controlling the species. However, the use of different herbicides has great advantages, such as lower production cost, broader spectrum and longer pest control time in crops, less environmental impact, as well as less probability of occurrence of resistant biotypes or tolerant species selected by applications. of a single molecule Therefore, these alternatives can be considered viable options for production systems.

S. latifolia have a wide distribution in the American continent, standing out in Brazilian agricultural areas of Maranhão, Tocantins, Piauí, and Bahia, becoming a problem since this region is considered one of the largest grain producers in Brazil. The results of this experiment support several studies in literature. GALLON et al. (2019) observed that the herbicides sulfentrazone and s-metolachlor suppressed the emergence of *S. latifolia* and *R. brasiliensis*; diclosulam were effective only on *R. brasiliensis*.

Trifluralin was not effective in controlling *S. latifolia* which is eudicotyledonous (family Rubiaceae). Trifluralin is highly effective in controlling monocotyledonous weeds such as *Digitaria insularis* and *D. horizontalis*, however, it may be less effective in controlling some species of eudicotyledons (MACHADO et al. 2016). Although the general recommendation is using trifluralin mainly in the control of monocotyledonous weeds, it was observed by DOS SANTOS et al. (2018) that, in cotton culture, trifluralin + diuron and promethrin + trifluralin provided effective control of *S. latifolia* at 20 and 35 days after application. In addition, the treatments caused low phytotoxicity in the culture.

In the evaluation at 14 DAE, the herbicide s-metolachlor was not efficient, which corroborates the results observed by LIMA et al. (2019) of the species *S. densiflora*, although in application in the post-emergence of the species. On the other hand, MARTINS & CHRISTOFFOLETTI (2014) verified that the use of the herbicides diclosulam, s-metolachlor, metribuzin, pendimethalin, imazaquim and sulfentrazone applied in pre-emergence were effective in *S. densiflora* control. In this study, the control of this species showed a high increase when evaluated at 28 and 42 days after emergence, culminating in approximately 80% control.

A study with sequential applications in *S. verticilata* plants in advanced development stages showed that chlorimuron-ethyl + glyphosate with diquat sequence and ammonium glufosinate had an increase in control and efficacy above 95%. Chlorimuron-ethyl applied alone showed satisfactory results with the use of a higher dose of ammonium glufosinate (88.77%) (JERÔNIMO et al. 2021).

According to LIMA et al. (2019), for satisfactory *S. densiflora* control in post-emergence, the herbicides glufosinate ammonium, flumioxazin, glyphosate + flumioxazin, and glyphosate + saflufenacil were recommended, considering the phenological stages of 4 or 8 fully expanded leaves. In addition, a direct relationship with biomass production was verified, in which the best treatments provided the lowest biomass accumulations of the shoot.

The combined or sequential use of two or more herbicides on the same crop is an improvement in weed control strategies. This practice can increase herbicide action spectrum; also, it allows the reduction of rates, leading to lower risk of phytotoxicity, lower residual effect and cost reduction (SINGH 2016).

CONCLUSION

For the control of resistant biotypes of E. indica to glyphosate, the herbicides s-metolachlor, pyroxasulfone + flumioxazin, diuron and trifluralin applied pre-emergence were efficient and can be used as a tool in the management of this weed species.

The herbicides s-metolachlor, pyroxasulfone + flumioxazin and diclosulam applied pre-emergence showed satisfactory control of S. latifolia, which is a species that is difficult to control with glyphosate.

However, in some cases, to enhance the control of herbicides such as diclosulam in E. indica, as well as diuron and trifluralin in the management of S. latifolia, sequential applications of diquat or ammonium glufosinate, acting as desiccants, were necessary. These additional strategies proved effective in the efficient management of these weeds, contributing to the preservation of agricultural crops.

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