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CROP PROTECTION

Importance of sequential herbicide application in the control of *Elephantopus mollis*

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ABSTRACT: *Elephantopus mollis, popularly known as elephant paw or sussuaiá, is a species that has recently emerged as a weed affecting grain crops. This study aimed to evaluate the differential sensitivity of biotypes of E. mollis obtained from agricultural and nonagricultural areas and to determine the best combinations of herbicides applied at different stages of development for controlling this species. Three experiments were conducted. In the differential sensitivity experiment, 10 herbicides were used in 2 biotypes in 2 stages of development. The dose–response experiment was conducted using 8 doses of 7 herbicides. The field experiment was conducted in an area with weed issues to validate the results of previous experiments. The biotype from the agricultural area showed lower sensitivity to herbicides than the biotype from the nonagricultural area. The contact herbicides initially presented better control; however, the weed shortly showed re-growth due to the presence of buds in the plant crown. Isolated application of 2.4-D amine at doses between 1005 and 1675 g a.e. ha^{-1} demonstrated 25% control. When 2,4-D amine was followed by paraquat application (400 g a.i. ha^{-1}), the control observed was between 51% and 68%. The best treatment for the control of completely developed weeds is 2,4-D amine + glyphosate mixture (1340 + 1080 g a.e. ha^{-1}), followed by sequential paraquat application.*
Key words: *elephant paw, Sussuaiá, 2,4-D amine, glyphosate.*

A importância da aplicação sequencial no controle de *Elephantopus mollis*

RESUMO: *Popularmente conhecida como pata de elefante ou sussuaiá, Elephantopus mollis, é uma espécie que recentemente surgiu como uma planta daninha em lavouras de cultivos de grãos. Objetivou-se com este estudo avaliar a sensibilidade diferencial de biótipos de E. mollis oriundos de áreas agrícolas e não agrícolas e determinar as melhores combinações de herbicidas aplicados em diferentes estádios de desenvolvimento para o controle desta espécie. Foram realizados três experimentos. No experimento de sensibilidade diferencial foram utilizados dez herbicidas em dois biótipos em duas fases de desenvolvimento. O experimento de dose resposta foi conduzido com oito doses de sete herbicidas. O experimento a campo foi realizado em uma área que apresenta problemas com a planta daninha para validar os resultados dos experimentos anteriores. O biótipo oriundo de área agrícola apresentou menor sensibilidade aos herbicidas quando comparado ao biótipo oriundo de área não agrícola. Os herbicidas de contato inicialmente apresentam controle superior, mas logo a planta apresenta rebrote em função de gemas presentes no colo da planta. A aplicação isolada de 2,4-D com doses entre 1005 e 1675 g e.a ha^{-1} possui controle de 25%. Quando o 2,4-D é seguido da aplicação de paraquat (400 g i.a ha^{-1}) o controle passa a ser entre 51 e 68%. O melhor tratamento para o controle de plantas desenvolvidas é a mistura de 2,4-D + glyphosate (1340 + 1080 g e.a ha^{-1}) com aplicação sequencial de paraquat.*
Palavras-chave: *pata de elefante, Sussuaiá, 2,4-D amina, glyphosate.*

INTRODUCTION

The soybean crop, one of the main crops cultivated in Brazil, is the principal commodity when it comes to generating foreign exchange income for the country. However, there are obstacles limiting productivity, thereby causing losses. These include interference caused by weeds in the initial stages of development, with losses as high as 95% (BARNES et al., 2018) and rendering harvesting unfeasible in extreme cases. Weeds, having mechanisms that enable them to thrive in adverse environments, can reduce productivity as well as damage the crop quality, leading to uneven maturation and loss of grain quality, or can act as hosts for pests or diseases that may eventually affect the crop (OLIVEIRA JUNIOR et al., 2011).

With the introduction of glyphosate-resistant soybean and simplification of weed control, which essentially involves the exclusive use of

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this herbicide, cases of glyphosate tolerance and resistance have emerged, creating one of the major issues encountered in soybean, corn, and cotton crop cultivation currently. It is becoming increasingly difficult to control the weed *Elephantopus mollis* (elephant's paw or sussuaiá), which was previously absent in agricultural production systems (BALBINOT, 2016). *E. mollis*, belonging to the family Asteraceae is a perennial herbaceous plant with medicinal potential (WU et al., 2017) and comprises a slightly lignified base and extremely short branches (BUNWONG et al., 2014). It is native to the American continent and is found throughout Brazil (FRANCISCO et al., 2019). Flowers are purplish, arranged in terminal and axillary capitula and protected by bracts (BUNWONG et al., 2014). New leaves bud underneath the existing leaves, which indicates that the meristems are protected, thereby enabling the weed to resume growth after a period of stress. Its perpetuation in the field mainly occurs via rhizomes, which explain its occurrence in coppices within the area.

Difficulties in controlling this weed are currently being reported. The herbicide glyphosate does not cause injury to the point of reducing the population. Moreover, considering that *E. mollis* ceases its metabolism during the cold period, herbicides used on winter crops do not impact the weed's development. Pre-seeding desiccation using contact herbicides, such as paraquat, even at high doses, only causes the weed to present necrosis and lose turgescence for a few days before recovering growth via new shoots.

The presence of a xylopodium at the base of *E. mollis* may be the structure responsible for the weed's ability to produce new shoots because contact herbicides do not reach this site. In Brazil, there are no records of any commercial products or any concrete studies regarding the control of *E. mollis*; therefore, there is a demand for studies on feasible means of controlling it. This study aimed to evaluate the differential sensitivity of biotypes of *E. mollis* from agricultural and nonagricultural areas and to determine the best combinations of herbicides applied at different stages of development to control this species.

MATERIALS AND METHODS

Three experiments were conducted to determine a method for the control of *E. mollis.* The differential sensitivity and dose–response experiments were conducted in a greenhouse in a controlled environment in the municipality of Sertão–Rio Grande do Sul, Brazil (28°02'46" S, 52°16'00" W) in 2016. The differential sensitivity experiment was conducted between the months of March and July 2016, in 2-L vessels filled with substrate. The dose–response experiment was conducted between September and December of the same year in 0.5-L vessels. For the two experiments conducted in the greenhouse, the mean temperatures were 22.3 °C ± 3.2 °C and 25.8 °C ± 4.1 °C, and the relative air humidity was 73.2% ± 6.6% and 62.0% ± 7.2%. The field experiment was conducted between September and November 2017 in a grain production area having *E. mollis* presence at Fazenda Cazaroto, São João, in the municipality of Sertão–Rio Grande do Sul, Brazil (28°03'77" S, 52°25'19" W).

In the differential sensitivity experiment, a completely randomized experimental design having a trifactorial arrangement (2 × 2 × 11) with four replications was followed. The first factor comprised two biotypes of *E. mollis*—one from an agricultural area with grain cultivation where the experiment was subsequently conducted in the field and the other from a nonagricultural area (lawn). The second factor comprised two stages of plant development—vegetative (3–4 leaves) and reproductive (flowering). The third factor comprised the application of 10 post-emergent herbicidal treatments along with the control (Table 1).

The dose–response experiment was conducted as four repetitions of the sprinkling of 8 doses of 7 herbicides or mixtures (Table 2). For the field experiment, the experimental design involved randomized blocks with subdivided plots, and four replications were employed. The main plot was comprised sprinkling 8 treatments of herbicides, either individual herbicide or mixtures, along with the control (Table 1), or the subplot included sequential or non-sequential sprinkling of the herbicide paraquat (400 g a.i. ha^{-1}) at 28 days after the first application.

In all three experiments, the herbicidal treatments were applied using a 200 kPa CO_2-pressurized sprayer, providing 180 L ha^{-1}, and Teejet XR11001 tips. Visual control evaluations in *E. mollis* were conducted via a visual examination to determine the effect of the herbicides, using a scale of 0–100, where 0 indicates the absence of symptoms and 100 indicates total weed control (FRANS & CROWLEY, 1986).

The data obtained from the field and differential sensitivity experiments were analyzed using the Shapiro–Wilk normality test to determine the need for data transformation. When necessary, data were transformed into "root of x + 1" to stabilize variances. Data were assessed using analysis of variance, followed by a comparison of means using

Table 1 - Relationship among herbicides, doses, concentrations/formulations, and manufacturers used in the field and differential sensitivity experiments (IFRS, Sertão–RS, 2017).

Common names	Trade name	Rates g a.i. ha^{-1}	Concentration/ formulation	Manufacturer
---Differential sensitivity experiment---				
Untreated (control)	--	--	--	--
Paraquat (Prqt)	Orbit	600	200 SL	Sinon
Glyphosate (Gly)	Roundup WG (R WG)	1080[1]	720 WG	Bayer
Saflufenacil (Saf)	Heat	35	700 WG	Basf
Pyraflufen	Kabuki	8,75	25 EC	Nichino
2,4-D amine (2,4-D)	Aminol 806	1340[1]	806 S	Adama
Chlorimuron	Classic	30	250 WG	Corteva
Glufosinate	Finale	400	200 SL	Bayer
Gly + Saf	R WG + Heat	1080[1] + 35	720 WG + 700 WG	Bayer + Basf
Gly + pyraflufen	R WG + Kabuki	1080[1] + 8,75	720 WG + 25 EC	Bayer + Nichino
Gly + chlorimuron	R WG + Classic	1080[1] + 30	720 WG + 250 WG	Bayer + Corteva
---Field experiment---				
Untreated (control)	--	--	--	--
Gly / Prqt	R WG / Orbit	1080[1] / 400	720 WG / 200 SL	Bayer / Sinon
Gly + Saf/Prqt	R WG + Heat / Orbit	1080[1] + 35 / 400	720 WG + 700 WG / 200 SL	Bayer + Basf / Sinon
Gly + 2,4-D/Prqt	R WG + Aminol / Orbit	1080[1] + 1340[1] / 400	720 WG + 806 S / 200 SL	Bayer + Adama / Sinon
2,4-D/Prqt	Aminol / Orbit	670[1] / 400	806 S / 200 SL	Adama / Sinon
2,4-D/Prqt	Aminol/ Orbit	1005[1] / 400	806 S / 200 SL	Adama / Sinon
2,4-D/Prqt	Aminol/ Orbit	1340[1] / 400	806 S / 200 SL	Adama / Sinon
2,4-D/Prqt	Aminol/ Orbit	1675[1] / 400	806 S / 200 SL	Adama / Sinon

[1]g a.e. ha^{-1}.
Abbreviations: SL = soluble concentrate; WG = water-dispersible granule; EC = emulsifiable concentrate; S = solution.

Tukey test ($p \leq 0.05$), when the F test of the analysis of variance was significant ($p \leq 0.05$).

For the dose–response experiment, regressions were performed using the SigmaPlot program, version 12.5, establishing the ratio between the percentage of the control and dose of the herbicide used. Nonlinear regression models were adjusted for the response variables using the three-parameter logistic model, according to STREIBIG (1988):

$$y = \frac{a}{\left[1 + \left(\frac{x}{b}\right)^{c}\right]}$$

where, "y" is the control percentage; "x" is the herbicide dose in g a.i. ha^{-1}; and "a", "b" and "c" are parameters estimated by the equation, where "a" is the amplitude between the maximum and minimum point of the variable; "b" is the dose corresponding to 50% weed control (C_{50}); and "c" is the slope of the curve around "b". C_{80} and C_{95} values were determined using the inverse equation, according to CARVALHO et al. (2005):

$$x = b\left(\left|\frac{a}{y} - 1\right|\right)^{\frac{1}{c}}$$

RESULTS AND DISCUSSION

Differential sensitivity experiment

Only the interactions "biotypes × herbicides" and "stage × herbicides" were significant (Tables 3 and 4, respectively). Regarding biotypes, the lawn biotype showed higher sensitivity to herbicides than the agricultural area biotype (Table 3). Chlorimuron did not exhibit satisfactory control in either of these biotypes. The herbicide pyraflufen, a PROTOX inhibitor, was more efficient in the nonagricultural areas area biotype. The higher sensitivity of the lawn biotype than the agricultural area biotype was expected because the recurrent application of herbicides having the same mechanism of action in the agricultural area results in weed

Table 2 - Relationship among herbicides, doses, concentrations, and formulations used in the dose–response experiment (IFRS, Sertão–RS, 2017).

Common names	Mechanism of action	--------------------------------Rates (g a.i. ha^{-1})---------------------------------						
		1/8	1/4	1/2	1X	2X	4X	8X
Paraquat	PS I Electron Diversion	75	150	300	600	1200	2400	4800
Glufosinate	In. of Glutamine Synthetase	75	150	300	600	1200	2400	4800
Pyraflufen	Inhibition of PROTOX	1,09	2,18	4,38	8,75	17,5	35	70
Saflufenacil	Inhibition of PROTOX	4,38	8,75	17,5	35	70	140	280
Chlorimuron	Inhibition of ALS	3,75	7,5	15	30	60	120	240
Glyphosate (Gly)	Inhibition of EPSPS	135[1]	270	540	1080	2160	4320	8640
Pyraflufen + Gly	PROTOX + EPSPS	1,09[2]	2,18	4,38	8,75	17,5	35	70
Saflufenacil + Gly	PROTOX + EPSPS	4,38[2]	8,75	17,5	35	70	140	280
Chlorimuron + Gly	ALS + EPSPS	3,75[2]	7,5	15	30	60	120	240
2,4-D amine	Auxin mimics	167,5[1]	335	670	1340	2680	5360	10720

[1]g a.e. ha^{-1}. [2]In all doses of the treatments “Pyraflufen + Gly”, “Saflufenacil + Gly” and “Chlorimuron + Gly”, glyphosate was added at 1080 g a.e. ha^{-1}.

Abbreviations: SL, soluble concentrate WG, water-dispersible granule; EC, emulsifiable concentrate; S, solution; Conc, Concentration.

population with greater resistance to these herbicides (Yu et al., 2013).

Regarding to the stage of plant development, the behavior of the herbicides was similar in both phases (Table 4). For the herbicides glyphosate, pyraflufen, and glufosinate, at 57 days after application (DAA), the control levels were 31%, 25%, and 20% higher in the vegetative phase than that in the reproductive phase. With plant development, the absorption and translocation of herbicides become increasingly limited and the mechanisms of detoxification become increasingly effective (OLIVEIRA JUNIOR et al., 2011). However, some herbicides that control the species of the Asteraceae family did not present satisfactory control in the vegetative phase of *E. mollis* (Table 4). This demonstrates that this species may present barriers to absorption and translocation as well as elaborate mechanisms of detoxification of herbicides and their effects in the vegetative phase itself.

Regarding the efficiency of the herbicides in this experiment, in the evaluations performed at 14 DAA, the contact herbicides and mixtures showed the best results (Tables 3 and 4). In the evaluation at 57 DAA, the contact herbicides began losing efficiency owing to plant regrowth, and systemic herbicides showed better performance. *E. mollis* contains rhizome-developing activity and is capable of developing shoots from the existing leaves. Contact herbicides are unable to reach the region where the shoots occur. In the final evaluation at 81 DAA, the best results were obtained in the treatments using systemic herbicides that showed a good mobility within the plant, such as the combination of 2,4-D amine and glyphosate with saflufenacil or chlorimuron. The exception was the herbicide glufosinate, which presented medium mobility within the plant and resulted in high control at 81 DAA.

Dose–response experiment

The visual control data fit the three-parameter logistic model. R^2 values were between 0.97 and 0.99, and the significance of the adjustments, denoted by p-value was < 0.0001. The dose required for the control of 50% of the population (C_{50}) and that required for the control of 80% and 95% of the population (C_{80} and C_{95}) were determined via model adjustment and using the inverse equation, respectively. The C_{80} and C_{95} values are important from a practical viewpoint. The C_{80} value is the dose needed to obtain 80% control, which is the minimum acceptable control. However, in cases where a new instance of resistance or tolerance is being observed, it is considered that the biotype should be eradicated to prevent the spread of the issue. Therefore, C_{95} values were also evaluated for evaluation of the results. C_{80} and C_{95} values will be compared with the maximum-recommended dose for the control of

Table 3 - Visual control (%) of *Elephantopus mollis* at 14, 35, 57, and 81 days after application (DAA) as a function of the interaction between biotypes (agricultural area and non-agricultural area) and herbicides.

Herbicide	---------14 DAA--------				-----------35 DAA---------				-----------57 DAA----------				------------81 DAA------------			
	--Lawn--		--Crop--		---Lawn---		---Crop---		---Lawn---		----Crop----		---Lawn---		-----Crop-----	
Paraquat	71	aBC[1]	48	bB	76	aA	66	aAB	31	aCD	11	bCD	35	aBCD	30	aDEF
Glyphosate	38	aDE	18	bC	8	aDE	18	aC	89	aA	42	bBC	78	aA	49	bBCDE
Saflufenacil	93	aA	96	aA	67	aAB	85	aA	70	aAB	68	aAB	65	aAB	68	aABCD
Pyraflufen	28	aEF	8	bC	46	aABCD	27	aBC	44	aBC	1	bD	54	aABC	4	bF
2,4-D amine	12	aFG	11	aC	10	aCDE	10	aC	92	aA	91	aA	92	aA	97	aA
Chlorimuron	5	aG	2	aC	3	aE	15	aC	8	aD	11	aCD	19	aCD	20	aEF
Glufosinate	90	aAB	88	aA	79	aA	71	aA	93	aA	87	aA	90	aA	79	aABC
Glyphosate + saflufenacil	99	aA	98	aA	75	aA	96	aA	98	aA	90	aA	90	aA	90	aAB
Glyphosate + pyraflufen	54	aCD	49	aB	52	aABC	65	aAB	92	aA	50	bB	93	aA	48	bCDE
Glyphosate + chlorimuron	18	aEFG	12	aC	3	aE	0	aC	95	aA	60	bAB	83	aA	85	aABC
Untreated (control)	0	aG	0	aC	0	aE	0	aC	0	aD	0	aD	0	aD	0	aF

[1]Uppercase letters denote the comparison of herbicide treatments within the same biotype (column), and lowercase letters denote the comparison of herbicide treatments within different biotypes (row). Means followed by the same letter, either lowercase or uppercase, are not significantly different according to the Tukey test at 0.05.

dicotyledonous weeds in the pre-sowing of soybean. In the absence of this specific information, the maximum-recommended dose for weed control in the soybean crop was used, and in the absence of that information, the maximum-recommended dose for any weed in any annual crop was used (Table 5).

Paraquat caused significant injury in the initial evaluations. However, the weed presented considerable re-growth and C_{80} and C_{95} values were above the maximum-recommended dose, based on the evaluation performed at 35 DAA (Table 5). Isolated glyphosate, chlorimuron, and glyphosate + chlorimuron applications demonstrated low visual weed control. According to the parameter "a" of the equation, which estimates the amplitude between the minimum and maximum control, it was verified that it 100% control of the weed population cannot be achieved despite using doses 8 times the recommended dose. The herbicide 2,4-D amine presented a slow evolution of symptoms observed in the weed. This herbicide was effective against *E. mollis* only at 81 DAA when the dose for C_{80} was 636 g a.e. ha^{-1}. However, C_{95} value was above the maximum-recommended dose, demonstrating the need to perform sequential applications using other herbicides to complement the control. The herbicide glufosinate presented similar behavior to that of systemic herbicides, with a gradual reduction in C_{80} and C_{95} values. At 81 DAA, C_{80} and C_{95} values were below the maximum-recommended doses.

Isolated pyraflufen and saflufenacil applications showed the same behavior as that shown by the herbicide paraquat, enabling an elevated re-growth of the weed. However, when combined with glyphosate, C_{80} values were below the maximum-recommended dose. This demonstrates the synergistic effect of the combination of glyphosate with pyraflufen or saflufenacil; in their isolated applications, glyphosate and these herbicides showed limited control over time. The synergistic effect of these herbicides with glyphosate is caused by the increase in the absorption and translocation of both herbicides in the plant, thereby reaching a higher dose at the site of action and resulting in better control (FIGUEIREDO, 2015).

Field experiment

Results of the field experiment showed that isolated glyphosate application presented visual control of < 10% until 21 DAA, reaching 16% at

Table 4 - Visual control (%) of *Elephantopus mollis* at 14, 35, 57, and 81 days after application (DAA) as a function of the interaction between stages (vegetative and reproductive) and herbicides.

Herbicide	------------14 DAA------------				--------35 DAA-------				-------------57 DAA------------				------------81 DAA------------			
	-----Veg.-----		---Rep.---		--Veg.--		--Rep.--		-----Veg.-----		----Rep.----		-----Veg.-----		---Rep.---	
Paraquat	64	aB[1]	55	aB	68	ns	73	ns	29	aCDE	12	aC	48	aBCD	17	bCD
Glyphosate	31	aCD	24	aC	21		5		82	aAB	50	bB	85	aAB	42	bBC
Saflufenacil	95	aA	94	aA	76		75		73	aAB	65	aAB	67	aABC	67	aAB
Pyraflufen	28	aCDE	7	bCD	45		28		35	aCD	10	bC	38	aCDE	21	aCD
2,4-D amine	8	aEF	14	aCD	10		10		94	aA	88	aA	92	aA	97	aA
Chlorimuron	5	aF	2	aD	15		3		14	aDE	4	aC	16	aDE	23	aCD
Glufosinate	88	aA	89	aA	86		84		100	aA	80	bAB	100	aA	69	bAB
Glyphosate + saflufenacil	98	aA	98	aA	91		80		97	aA	92	aA	95	aA	85	aA
Glyphosate + pyraflufen	44	bBC	59	aB	73		43		60	bBC	82	aAB	63	aAB	78	aAB
Glyphosate + chlorimuron	12	aDEF	17	aCD	2		1		73	aAB	82	aAB	97	aA	72	aAB
Untreated-check	0	aF	0	aD	0		0		0	aE	0	aC	0	Ae	0	aD

[1]Uppercase letters denote the comparison of herbal treatments within the same phenological stage (column), and lowercase letters denote the comparison of herbal treatments within different phenological stages (row). Means followed by the same letter, either lowercase or uppercase, are not significantly different according to the Tukey test at 0.05.

28 DAA (Table 6). Increasing doses of 2.4-D amine differed only in the evaluation performed at 28 DAA, where the control observed at the doses of 670 and 1005 g a.e. ha^{-1} was lower than that observed with the remaining doses of 2.4-D amine. The combination of glyphosate + 2.4-D amine presented a control of 38% at 28 DAA, whereas the combination of glyphosate + saflufenacil showed greater visual control than the other treatments with a mean control of 60% in the evaluations performed between 7 and 28 DAA (Table 6).

At 28 DAA, sequential paraquat application was performed. The levels of control increased compared with the treatments that did not receive this sequential application (Table 7) The exceptions were the glyphosate and glyphosate + saflufenacil treatments, for which some evaluations showed no difference, regardless of the presence or absence of paraquat. The greatest increases in control following sequential application were observed in the treatments where the initial application presented lower efficiency. On averaging the control obtained using the treatments, sequential paraquat application increased the control of *E. mollis* by 44% compared with isolated application. Following a sequential paraquat application, treatments containing 2,4-D amine presented higher values of visual control based on the evaluation performed at 35 DAA. Plants sprinkled with glyphosate or glyphosate + saflufenacil showed gradual regrowth, reducing the visual weed control to 15%. At the end of the experiment, 50 days after the sequential application (DAS), treatments with 2.4-D amine (1675 g a.e. ha^{-1}) and glyphosate + 2.4-D amine, both with sequential paraquat application, presented the highest levels of visual control, with 85% and 94%, respectively (Table 7).

Low levels of visual control before sequential paraquat application demonstrated the difficulty in controlling *E. mollis* in the field. Isolated glyphosate application has shown low efficiency in several weeds. Therefore, the use of mixtures enables the spectrum of control to be expanded (RONCHI et al., 2002). The lethal effect of the 2,4-D amine application requires a longer duration to appear compared with other mechanisms of action (SENSEMAN, 2007). This situation would explain the lack of differences in control between the doses of 2.4-D amine in the first evaluations before sequential application (Table 6), with a dose-related

Table 5 - Parameters of the logistic equation and C_{50}, C_{80}, and C_{95} values as a function of visual control (%) of *Elephantopus mollis* in response to herbicide application at 14, 35, and 81 days after application (DAA).

Herbicide	Evaluation	a[1]	c[1]	C_{50}[2]	Deviation	C_{80}[2]	C_{95}	Recommended maximum dose (g a.i. ha^{-1})
Paraquat	14 DAA	98,9	-2,43	86,9	2,7	157,4	323,3	400
	35 DAA	116,1	-0,73	257,1	181,6	764,7	2019,4	
	81 DAA	106,0	-1,18	265,2	35,8	687,4	1648,4	
Glyphosate	14 DAA	65,1	-0,94	14256,2	17805,4	>85211,3	>48764,3	1080[3]
	35 DAA	32,9	-1,36	260,5	16,0	>384,6	>356,1	
	81 DAA	87,7	-1,66	287,4	16,4	>1177,3	>1348,4	
2,4-D amine	14 DAA	106,2	-1,42	2198,0	370,3	4824,2	9906,1	1005[3]
	35 DAA	119,6	-0,84	1494,2	335,1	3451,2	7463,9	
	81 DAA	101,5	-1,71	295,0	29,2	636,1	1415,8	
Glufosinate	14 DAA	95,7	-1,30	96,0	13,7	335,9	4195,2	600
	35 DAA	100,9	-1,17	124,1	19,1	390,9	1334,4	
	81 DAA	102,4	-1,46	88,7	14,0	212,1	509,5	
Pyraflufen	14 DAA	97,8	-2,02	4,9	0,7	10,2	27,9	10
	35 DAA	143,9	-0,50	16,7	18,8	26,2	63,0	
	81 DAA	130,8	-0,70	9,5	7,2	18,2	38,3	
Pyraflufen + Glyphosate	14 DAA	110,9	-0,78	2,4	0,5	8,1	23,5	10
	35 DAA	151,3	-0,45	13,1	17,6	16,9	41,9	
	81 DAA	106,7	-0,83	1,9	0,2	7,1	23,7	
Saflufenacil	14 DAA	103,3	-1,20	10,6	0,7	29,6	80,8	35
	35 DAA	101,2	-1,40	9,40	0,20	24,3	66,0	
	81 DAA	103,4	-1,20	15,2	1,4	42,3	114,7	
Saflufenacil + Glyphosate	14 DAA	97,9	-1,96	4,6	0,1	10,0	27,5	35
	35 DAA	98,2	-1,13	3,3	0,7	12,2	66,3	
	81 DAA	102,0	-0,97	5,8	0,3	22,0	85,3	
Chlorimuron	14 DAA	6,4	-1,10	11,5	1,7	>12,4	>12,2	20
	35 DAA	60,7	-1,70	11,6	1,3	>26,8	>21,1	
	81 DAA	87,5	-1,30	17,0	1,3	>105,0	>119,8	
Chlorimuron + Glyphosate	14 DAA	48,1	-1,10	28,4	5,6	>65,5	>54,0	20
	35 DAA	60,6	-0,75	11,9	3,4	>78,7	>46,1	
	81 DAA	100,5	-0,90	7,0	1,1	31,8	165,9	

[1]a = amplitude between the maximum and minimum point of the variable; c = slope of the curve around C_{50}. [2]C_{50}, C_{80}, and C_{95} = dose required for 50%, 80%, and 95% control, respectively. [3]g a.e. ha^{-1}.

differentiation only occurring in the evaluation performed at 28 DAA. The combination of the herbicide 2,4-D amine and glyphosate improves weed control. Plants sprinkled with 2,4-D amine showed little re-growth capacity compared with those that received the other treatments. The high translocation capacity of 2,4-D amine and its mechanism of action in the weed can limit re-growth, rendering this herbicide fundamental for controlling this weed in agricultural production systems.

The devised glyphosate + 2.4-D amine mixture was efficient in the control of *Convolvulus arvensis* in wheat production areas (STONE et al., 2005) and *Conyza canadensis* during the winter period in the southern United States of America (WIESE et al., 1995). Control of the weed *Artemisia verlotorum*,

Table 6 - Visual control (%) of *Elephantopus mollis* at 7, 14, 21, and 28 days after application (DAA) as a function of spraying herbicides in the field experiment.

Herbicide	g a.e. ha^{-1}	-----7 DAA-----		-----14 DAA----		----21 DAA----		-----28 DAA-----	
Glyphosate	1080	2	c[2]	9	d	8	c	16	d
2,4-D amine	670	19	b	12	cd	10	bc	19	d
2,4-D amine	1005	15	b	14	cd	11	bc	24	cd
2,4-D amine	1340	22	b	18	bc	12	bc	30	bc
2,4-D amine	1675	24	b	19	bc	16	b	35	b
Glyphosate + 2,4-D amine	1080+1340	21	b	24	b	18	b	38	b
Glyphosate + saflufenacil	1080+35[1]	60	a	58	a	61	a	60	a
Untreated-check	--	0	c	0	e	0	d	0	e

[1]g a.i. ha^{-1}. [2]Means followed by the same letter in the columns are not significantly different according to the Tukey test at 0.05.

which, similar to *E. mollis* exhibits high re-growth capacity, was efficient using increasing doses of glyphosate + 2.4-D amine mixture (BRIGHENTI et al., 1994). Therefore, under the conditions in which the experiment was performed, the best control level of *E. mollis* was obtained using the glyphosate + 2.4-D amine application, followed by sequential paraquat application. Considering the possible ban of paraquat in Brazil in 2020 (ANVISA, 2017), the herbicide glufosinate and herbicides that inhibit the

Table 7 - Visual control (%) of *Elephantopus mollis* at 7, 21, 35, and 50 days after application (DAA) as a function of the interaction between herbicides and the presence or absence of sequential paraquat application in the field experiment.

Treatment	g a.e. ha^{-1}	---Paraquat (7 DAA)---				---Paraquat (21 DAA)---				---Paraquat (35 DAA)---				--Paraquat (50 DAA)--			
		Absence		Presence		Absence		Presence		Absence		Presence		Absence		Presence	
Glyphosate (Gly)	1080	15	bC[2]	59	aB	5	aAB	15	aDE	6	bCD	22	aD	10	aC	15	aE
2,4-D amine	670	27	bB	76	aAB	10	bAB	26	aCDE	14	bBCD	47	aC	30	bB	49	aD
2,4-D amine	1005	32	bAB	66	aAB	12	bAB	34	aBCD	24	bAB	51	aBC	35	bAB	65	aC
2,4-D amine	1340	35	bAB	74	aAB	21	bAB	58	aAB	25	bAB	62	aBC	40	bAB	80	aB
2,4-D amine	1675	39	bAB	68	aAB	18	bAB	41	aABC	22	bABC	68	aAB	39	bAB	85	aAB
Gly + 2,4-D amine	1080+ 1340	40	bAB	80	aA	26	bA	65	aA	35	bA	84	aA	44	bA	94	aA
Gly + saflufenacil	1080+ 35[1]	46	bA	78	aAB	8	aAB	15	aDE	6	aCD	15	aD	6	bC	14	aE
Untreated (control)	--	0	bD	60	aB	0	aB	9	aE	0	aD	9	aD	0	bC	12	aE

[1]g a.i. ha^{-1}.

[2]Uppercase letters denote the comparison of herbicide treatments having the same type of sequential paraquat application (presence or absence; column), and lowercase letters denote the comparison of herbicide treatments having the same type of sequential paraquat application (presence or absence; row). Means followed by the same letter, either lowercase or uppercase, are not significantly different according to the Tukey test at 0.05.

enzyme PROTOX may be promising substitutes for sequential application.

CONCLUSION

For most herbicides tested, *E. mollis* plants from lawn areas presented greater sensitivity to herbicides compared with those from agricultural areas. There was a similarity in the control levels between the vegetative and reproductive phases for most herbicides and doses used in this study. Among the isolated herbicide applications, glufosinate and 2,4-D amine were the most effective ones for controlling *E. mollis*. The glyphosate + 2,4-D amine mixture application, followed by sequential paraquat application presented high control of *E. mollis*.

DECLARATION OF CONFLICT OF INTEREST

The authors declare no conflict of interest. The funding sponsors had no role in the design of the study; in the collection, analysis, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

AUTHORS' CONTRIBUTIONS

All authors conceived and designed experiments. ALN and BC performed the experiments and statistical analyses of experimental data. All authors prepared the draft of the manuscript. All authors critically revised the manuscript and approved of the final version.

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