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Performance of pre-Emergent Herbicides in Soybean Under Contrasting Physiographic Conditions in the MATOPIBA Region, Brazil

Desempenho de Herbicidas Pré-Emergentes em Soja, Sob Diferentes Condições Fisiográficas, na Região do MATOPIBA, Brazil

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Abstract

Soybean crop has been produced in the Matopiba region, Brazil, mainly in two physiographic conditions: lowland and plateau. These different characteristics probably include variations in the weed diversity, soil properties, and herbicides performance. Thus, the aim of this study was to analyze

the performance of pre-emergent herbicides under different physiographic (lowland and plateau) in a soybean system. Two experiments were conducted during the rainy season, between January and April 2021, in commercial soybean fields located on Brejo and Mata Roma, Maranhão, Brazil. These experiments were installed in a randomized complete block design, white nine treatments and four replications. The treatments consisted in diclosulam, flumioxazine, imazethapyr, S-metolacloro, diclosulam + imazetapir, flumioxazine + imazethapyr, S-metolacloro + imazethapyr, and clomazone + carfentrazone, and no-treated herbicide. We evaluated the weed diversity, weed control and phytotoxicity ratings. Statistical analyses were realized for continuous, using the traditional analysis of variance (ANOVA) approach, with evaluation of the significance of effects using the F test ($p < 0,05$). We observed in the lowland (experiment 1) a higher weed diversity (+23%) and higher soil organic matter content (+40%), along with lower herbicides performance compared to the plateau physiograph (experiment 2). These findings indicate that soil physiography should be considered when selecting pre-emergent herbicide strategies for soybean systems in the MATOPIBA region. All treatments were selective to soybeans at the dosages and conditions tested. However, flumioxazin + imazethapyr was the most effective treatment.

Keywords: *Glycine max* (L.) Merril. Glyphosate-Resistant Weeds. Lowland. Plateau. Weed Seed Bank Dynamic.

Resumo

A soja tem sido produzida, principalmente em duas condições fisiográficas, na região de Matopiba, Brasil: baixão e chapada. Essas diferentes características provavelmente incluem variações na diversidade de plantas daninhas, propriedades do solo e desempenho dos herbicidas. Assim, o objetivo deste estudo foi analisar o desempenho de herbicidas pré-emergentes em diferentes condições fisiográficas (baixão e chapada), em um lavouras de soja. Dois experimentos foram realizados durante a estação chuvosa, entre janeiro e abril de 2021, em campos comerciais de soja localizados em Brejo e Mata Roma, Maranhão, Brasil. Esses experimentos foram instalados em delineamento de blocos casualizados, com nove tratamentos e quatro repetições. Os tratamentos consistiram em diclosulam, flumioxazina, imazetapir, S-metolacloro, diclosulam + imazetapir, flumioxazina + imazetapir, S-metolacloro + imazetapir, clomazona + carfentrazona e a testemunha (sem herbicida). Avaliou-se a diversidade e o controle de plantas daninhas, e a fitotoxicidade. As análises estatísticas foram realizadas para dados contínuos, utilizando a abordagem tradicional de análise de variância (ANOVA), com avaliação da significância dos efeitos utilizando o teste F ($p < 0,05$). Observou-se no baixão (experimento 1) uma maior diversidade de plantas daninhas (+23%) e maior teor de matéria orgânica do solo (+40%), ocasionando um menor desempenho dos herbicidas pré-emergentes. Esses resultados indicam que a fisiografia do solo deve ser considerada na seleção de estratégias de herbicidas pré-emergentes para sistemas de soja na região do MATOPIBA. Todos os tratamentos foram seletivos para a soja nas dosagens e condições testadas, no entanto, o tratamento mais eficaz foi flumioxazina + imazetapir.

Palavras-chave: *Glycine max* (L.) Merril. Baixão. Chapada. Dinâmica do Banco de Sementes. Plantas Daninhas Resistentes ao Glifosato.

1 Introduction

The soybean [*Glycine max (L.) Merril*] is one of the most important crops in the world. The market potential and its great adaptation to different soil and climatic conditions have led to its cultivation in many Brazilian regions (Silva *et al.,* 2025). Brazil is currently the largest producer with

47 million hectares and a grain production of 169 million tons in the 2024/2025 harvest (Santos *et al.,* 2025).

The Amazon-Cerrado region known as Matopiba, produces 32 million tons of soybeans, occupying 5.9 million hectares. This region comprises the states of Maranhão, Tocantins, Piaui, and Bahia. It is the region with the largest expansion in Brazil, and produces approximately 12% of the Brazilian soybean crop (Silva *et al.,* 2025).

In Matopiba, soybean cultivation occurs mainly under two physiographic conditions, referred to as plateau and lowland. The plateaus correspond to extensive areas of flat topography, original vegetation typical of the Brazilian savannah (Cerrado biome) and deep soils. The lowlands are characterized by low-relief portions, with native vegetation of babassu coconut (Coconut biome) and sloping soils (Almeida *et al.,* 2019).

These different characteristics may lead to variations in vegetation, soil properties, weed diversity, and preemergent herbicide performance (Almeida *et al.,* 2024; Salomão *et al.,* 2021). However, studies addressing these interactions under Matopiba conditions remain scarce in the scientific literature.

Chemical control is the main method used to suppress weeds in soybean crop systems due to its effectiveness, convenience and cost viability (Furtado *et al.,* 2025). It consists of the use of, which can be selective or non-selective to the crop, and applied before or after planting. Thus, pre-emergence chemical control comprises the application of residual herbicides to soil before the weeds and crop emergence (Silva *et al.,* 2024). The pre-emergence herbicides have a variable half-life in the soil, which allows control of the weed seed bank, avoids weed competition and reduces the glyphosate applications after planting. This can reduce selection pressure for glyphosate-resistant weeds (Adegas *et al.,* 2022).

Pre-emergent herbicides performance depends on some components, such as their physicochemical characteristics, physicochemical soil properties, relief, rainfall, weather conditions, straw amount in the soil surface, and management system (Khalil *et al.,* 2019).

Therefore, the hypothesis of this study is that soil physiography has interference in weed diversity and pre-emergent herbicides performance. Thus, the objective of this study was to analyze the performance of pre-emergent herbicide under conditions in a soybean system, in the Matopiba region, Brazil.

2 Material and Methods

2.1 Study location

The experiments were conducted during the rainy season, between January and April 2021 in two commercial soybean fields located in Brejo (experiment 1) (03°42'11" South, 42°56'19" West) and Mata Roma (experiment 2) (3º 14' 50" South, 43º 11' 13" West), Maranhão, Brazil. The soil in each experimental area was classified as Yellow Argisol cohesive dystrophic, according to the Brazilian Soil Classification System (Santos *et al.,* 2018). The chemical analysis (0-20 cm layer) is shown in Table 1.

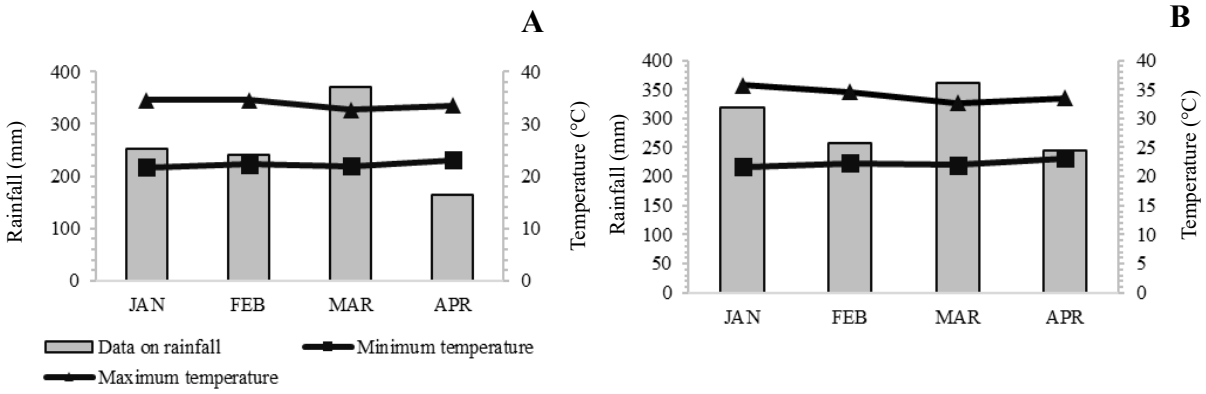
Table 1 - Soil chemical analysis at depths from 0 to 10 cm, and 10 to 20 cm, in two experiments (lowland/Coconut biome, and plateau/Cerrado biome)

Lowland (Experiment 1)															
			Sorptive Complex								**Sorptive Complex Saturation**				
Depth	pH	O.M.	P	K	Ca	Mg	Al	H+Al	BS	CEC	V	M	Ca	Mg	K
(cm)	$CaCl_2$	dag/kg	mg/dm^3	.....cmol/dm^3.....							.....%.....				
0-10	5.5	2.2	2.1	0.13	2.8	1.1	0	2	4	6	67	0	46.7	18.3	2.2
10-20	4.9	1.5	1.6	0.1	1.6	0.6	0	3.1	2.3	5.4	43	0	29.6	11.1	1.9
Plateau (Experiment 2)															
			Sorptive Complex								**Sorptive Complex Saturation**				
Depth	pH	M.O.	P	K	Ca	Mg	Al	H+Al	SB	CRC	V	M	Ca	Mg	K
(cm)	$CaCl_2$	dag/kg	mg/dm^3	.....cmol/dm^3.....							.....%.....				
0-10	5.2	1.3	1.9	0.06	1.4	0.5	0	1.6	2	3.6	54	0	38.9	13.9	1.7
10-20	4.9	0.9	1.8	0.03	1.2	0.4	0	1.9	1.6	3.5	47	0	34.3	11.4	0.9

Abreviations: O.M. – organic matter; P – phosphorus; K – potassium; Ca – calcium; Mg – magnesium; Al – aluminum; SB –basis sum; CEC – Cation exchange capacity; V – basis saturation. Observations: pH – measured by $CaCl_2$ method; P – measured by Mehlich 1 method.
Source: research data,

The climate of the study region is classified as tropical hot and humid (Aw) with an average annual temperature of 27 °C and medium rainfall of 1,800 mm. The rainy season occurs between January and June with an average annual relative humidity of 76% (Passos, Zambrzycki e Pereira, 2016). The rainfall data and maximum temperature and minimum temperature data are shown in Figure 1.

Figure 1 - Database of the rainfall (mm), maximum and minimum temperature (°C) for January to April 2021



(**A**) Experiment 1 and (**B**) Experiment 2. Database from INMET (2021).
Source: research data,

In experiment 1 plots were located in a lowland field (Coconut biome transition), while in experiment 2 plots were located located in a plateau field (Cerrado biome transition). Both fields were managed under a no-tillage system on Sudan-grass straw. The medium-late cycle cultivar FTR 3191 IPRO (group 9.1) was planted with an expected population of 150,000 plants per hectare and 0.50 m spacing.

2.2 Experimental arrangement

The experiment was carried out in a randomized complete block, whith nine treatments and four replications. The treatments consisted of control without pre-emergent herbicide, diclosulam (30 g a.i. ha^{-1}), flumioxazin (50 g a.i. ha^{-1}), imazethapyr (100 g a.e. ha^{-1}), S-metolachlor (1,200 g a.i. ha^{-1}), diclosulam + imazethapyr (30 g a.i. ha^{-1} + 100 g e.a. ha^{-1}), flumioxazin + imazethapyr (50 g a.i. ha^{-1}+100 g e.a. ha^{-1}), S-metolachlor + imazethapyr (1,200 g a.i. ha^{-1} + 100 g e.a. ha^{-1}), and clomazone + carfentrazone-ethyl (720 g a.i. ha^{-1} + 18 g a.i. ha^{-1}). Each plot occupied an extension of 18 m^2, where three central rows of 3 m length were evaluated.

The desiccation of fields was realized seven days before planting with glyphosate (2,477.1 g a.i. ha^{-1}). The pre-emergence treatments were applied on soybean planting, using a CO_2 pressurized backpack sprayer equipped with a six-point Magno 11002 AD boom, spaced 0.5 m apart. The equipment operated at a constant pressure of 2 bar and an application rate of 150 L ha^{-1}. The application started at 07:30 a.m. and was completed at 08:30 a.m., under environmental conditions recommended by ISO 5682-1:1996: air moisture (55 < RH < 90%); air temperature (25 < T < 30°C)

and wind speed (2 < V < 10 m/s).

2.3 Weed survey

Two phytosociological surveys were carried out in each experiment to evaluate weed occurrence and control. The first survey was performed one day before soybean planting (sixty samples spaced 15 m x 15 m, in six horizontal rows), and the second, was carried out 25 days after treatments applications (two samples in each experimental plot), using a 1 m^2 sampling quadrat. The weeds were identified using specialized literature (Lorenzi, 2014) and quantified to estimate phytosociological indices.

The phytosociological indices comprised: relative density, relative frequency, relative abundance, importance value index (IVI), Sorensen index (IS), and a weed control percentage for each treatment. The weed control was determined from quotient between no-treated density weeds and treated density weeds, using the following Equation 1.

$$Control\ (\%) = [(Density\ in\ control - Density\ in\ treatment)\ /\ Density\ in\ control] \times 100$$

The weed control percentage were classified as none or scarce control (0-40%), regular control (41-60%), sufficient control (61-70%), good control (71-80%), very good control (81-90%), and excellent control (91-100%). Treatments with equal to or greater than 80% were considered effective (Gonese; Weber, 1998; SBCPD, 1995).

Phytotoxicity ratings were estimated at 10, 18 and 25 days after herbicide application (DAA), using a adaptation of the Scale Model of the European Weed Research Community (EWRC, 1964), based on visual symptom assessment in soybean plants. Scores ranged from 0% (absence of phytotoxicity) to 100% (plant death).

2.4 Statistics analyses

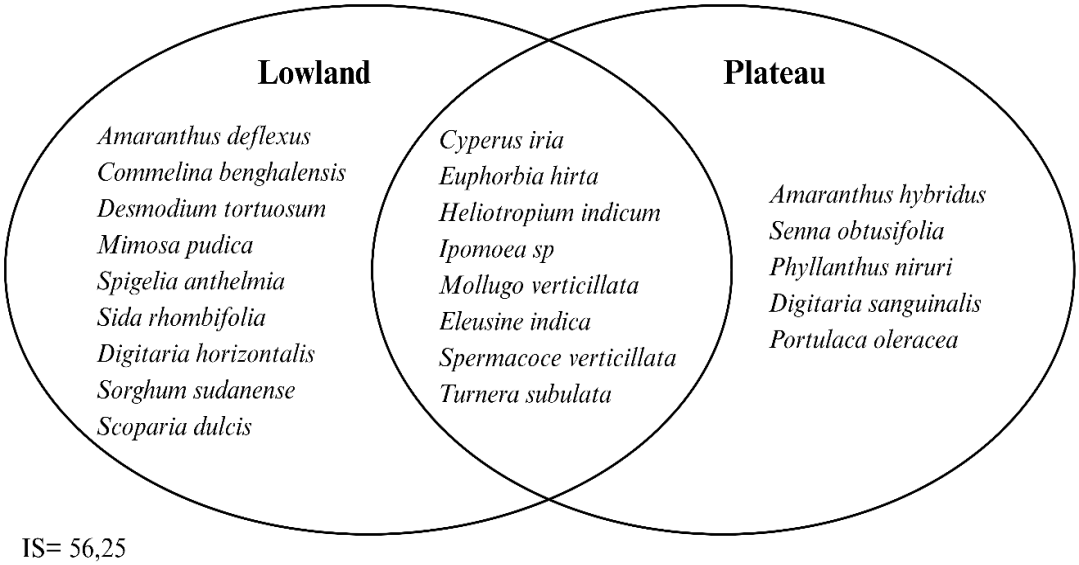
Statistical analyses were realized using the traditional analysis of variance (ANOVA) approach, with evaluation of the significance of effects using the F test for continuous variables (weed control and phytotoxicity ratings). The model assumptions were verified using the Shapiro-Wilk normality test ($p \leq 0.05$) and inspection of diagnostics associated with the residuals. When significant differences were observed between treatments ($p \leq 0.05$), the Scott–Knott test was applied for multiple comparison of means in each experiment (1 and 2). In turn, the data resulting from the phytosociological survey were analyzed using descriptive statistical techniques, with presentation of the sums and arithmetic mean in each experiment.

3 Results and Discussion

3.1 Weed survey

The weed survey identified 18 species, 18 genera, and 14 botanical families in the experiment 1 (lowland), and 14 species, 14 genera, and 11 botanical families in experiment 2 (plateau). Therefore, greater number species was observed in the lowland area. In turn, Sorensen Similarity analysis estimated an index of 56.25% between the two experiments (Figure 2).

Figure 2 - Illustration of exclusive and shared weeds under lowland (experiment 1) and plateau physiography (experiment 2). Identifications were made using specialized literature (Lorenzi, 2014) and phytosociological survey techniques. The database was nominally plotted in a Venn diagram



IS= 56,25

Source: research data,

Some species as such *C. iria*, *E. hirta*, *H. indicum, I. triloba*, *M. verticillata*, *C. echinatus*, *E. indica*, *S. verticillata* and *T. subulata* occurred in both experiments, reflecting an adaptation to agronomic management realized. Among these species, *C. iria*, *E. indica* and *S. verticillata* are listed as resistant and tolerant to glyphosate in several Brazilian states, such as Paraná (Takano *et al.,* 2017), Rio Grande do Sul (Vargas *et al.,* 2013) and Bahia (Kalsing, *et al.,* 2020). Also in other countries, such as, Malaysia and Colombia (Villalba, 2009). Therefore, herbicide rotation and the use of pre-emergent herbicides are important strategies for weed resistance prevention and integrated weed management (Ponte *et al.,* 2024).

Pre-emergent herbicides performance

We observed differences statistically significant between treatments in experiments 1 and 2 ($p < 0,05$). In experiment 1, conducted in lowland physiography, obtained a control of 70% for monocotyledons and 43% for eudicotyledons species. (Table 2). The most effective treatments for monocotyledonous were flumioxazin + imazethapyr (98%), S-metolachlor + imazethapyr (92%), and S-metolachlor (87%) (Table 2).

Table 2 - Pre-emergent herbicides control on the different weed class (monocotyledonous and eudicotyledons), in the experiment 1 (lowland physiography) and experiment 2 (plateau physiography)

Experiment	Physiography	Treatment	Rate	Weed control (%)	
			g a.i or a.e ha-[1]	Monocotyledons	Eudicotyledons
1	Lowland	No-treated	--	0 g	0 f
1	Lowland	Diclosulam	30	52 e	81 c
1	Lowland	Flumioxazina	50	64 d	54 e
1	Lowland	Imazetapir	100	72 c	69 d
1	Lowland	S-metolachlor	1,200	87 b	8 f
1	Lowland	Dic + Ima	30 + 100	53 e	89 b
1	Lowland	Flu + Ima	50 + 100	98 a	96 a
1	Lowland	S-met + Ima	1,200 + 100	92 b	73 d
1	Lowland	Clo + Carf	720 + 18	39 f	6 f
2	Plateau	No-treated	--	0 c	0 c
2	Plateau	Diclosulam	30	100 a	97 a
2	Plateau	Flumioxazina	50	72 b	97 a
2	Plateau	Imazetapir	100	100 a	98 a
2	Plateau	S-metolachlor	1,200	100 a	94 a
2	Plateau	Dic + Ima	30 + 100	100 a	95 a
2	Plateau	Flu + Ima	50 + 100	100 a	100 a
2	Plateau	S-met + Ima	1,200 + 100	100 a	94 a
2	Plateau	Clo + Carf	720 + 18	81 b	42 b

Abreviations – Dic: diclosulam; Flu: flumioxazin; Ima: imazethapyr; S-met: S-metolachlor; Clo: clomazone; Car: carfentrazone. **Note –** means were compared from Scott–Knott test.
Source: research data.

On the other hand, the use of diclosulam, flumioxazin, and imazethapyr alone showed low control. That results are in accordance with Gazola *et al.* (2021) and Silva *et al*. (2025) who highlighted the importance of herbicide mixtures to broaden the weed control spectrum and to prevent the weed herbicide resistance in soybean systems.

It is important to note that the unsatisfactory performance of diclosulam and imazethapyr, alone or combined, as well as clomazone + carfentrazone and flumioxazin alone, may be related to their limited control spectrum on *C. iria, C. benghalensis,* and *E. indica* (Furtado *et al.,* 2025), which were identified in treatments plots. In addition, clomazone, diclosulam, and flumioxazin are highly lipophilic herbicides, and their adsorption to soil organic matter can reduce bioavailability (Carbonari *et al.,* 2019; Ovejero *et al.,* 2019). In experiment 1, soil organic matter content is proportionally 40% higher than in experiment 2 (Table 2), which may have induced to lower herbicide performance in experiment 1 (Carbonari *et al.,* 2016).

In contrast, for the eudicotyledons the use of diclosulam alone or in mixture with imazethapyr obtained satisfactory results, with percentages of 81 and 89%, respectively. In turn, the application of imazethapyr and S-metolachlor, alone or in mixture, obtained low performance, with percentages of 8 to 69% control (Table 2), possibly related to the narrow control spectrum of these herbicides on *S. verticillata, T. subulata, E. hirta, S. dulcis, and A. deflexus*, which were identified in these treatments. For the control of this species, the most effective treatments were flumioxazin + imazethapyr (96%), diclosulam + imazethapyr (89%), and diclosulam alone (81%). These results are in accordance with Furtado *et al.* (2025) and Silva *et al.* (2024) who obtained excellent control for these species using herbicides inhibitors of Protox and ALS, as well flumioxazine, imazethapyr and diclosulam.

In experiment 2, realized in a plateau physiography, an average control of 94% was estimated for monocotyledons and 90% for eudicotyledons, with ranges from 72 to 100% (monocotyledons) and 42 to 100% (eudicots), respectively (Table 2). Therefore, these results were apparently superior to experiment 1. This may be related to weed diversity and soil organic matter content, which can have interfered in pre-emergent herbicides performance. Except flumioxazin alone (monocotyledonous control) and clomazone + carfentrazone (eudicotyledonous control), all treatments were effective in experiment 2, obtaining a weed control above to 80%.

3.2 Phytotoxicity ratings of pre-emergent herbicides on soybean crop

There were no statistical differences between the treatments tested ($p > 0,05$). The phytotoxicity ratings estimated in both experiments ranged of 1 to 3%. Thus, all treatments were selective to soybean crop (Table 3).

Table 3 - Phytotoxicity ratings of pre-emergent herbicides on the soybean crop at 25 days after herbicides application (DAA)

Experiment	Physiography	Treatment	Rate	Phytotoxicity Rating
			g a.i or a.e ha-¹	%
1	Lowland	No-treated	--	--
1	Lowland	Diclosulam	30	2
1	Lowland	Flumioxazine	50	3
1	Lowland	Imazethapyr	100	2
1	Lowland	S-metolachlor	1,200	2
1	Lowland	Dic + Ima	30 + 100	2
1	Lowland	Flu + Ima	50 + 100	2
1	Lowland	S-met + Ima	1,200 + 100	2
1	Lowland	Clo + Carf	720 + 18	2
2	Plateau	No-treated	--	--
2	Plateau	Diclosulam	30	2
2	Plateau	Flumioxazina	50	1
2	Plateau	Imazetapir	100	2
2	Plateau	S-metolachlor	1,200	2
2	Plateau	Dic + Ima	30 + 100	1
2	Plateau	Flu + Ima	50 + 100	1
2	Plateau	S-met + Ima	1,200 + 100	2
2	Plateau	Clo + Carf	720 + 18	1

Abreviations – Dic: diclosulam; Flu: flumioxazin; Ima: imazethapyr; S-met: S-metolachlor; Clo: clomazone; Car: carfentrazone.
Source: research data.

These results are consistent with those obtained in the literature, such as Gazola *et al.* (2021), Silva *et al.* (2024), and Furtado *et al.* (2025), in experiments that tested the performance of preemergent herbicides in no-till and/or conventional soybean systems.

The results obtained this study indicate that the use of pre-emergent herbicides in soybean systems is effective for controlling weeds with a history of glyphosate resistance. The best performance occurred with flumixazin + imazethapyr application. However, the positioning of these herbicides must be carried out according to well-planned technical aspects.

This study signalizes that physiography interferes in the pre-emergent performance. This occurs due to variations in the floristic diversity of weeds and organic matter content in the soil. Therefore, there must be an adequate choice of active ingredients, mechanisms of action, and dosages, especially in crop systems of the MATOPIBA region.

4 Conclusion

We observed in the lowland (experiment 1) a higher weed diversity (+23%) and higher soil

organic matter content (+40%), along with lower herbicides performance compared to the plateau physiograph (experiment 2). These findings indicate that soil physiography should be considered when selecting pre-emergent herbicide strategies for soybean systems in the MATOPIBA region. All treatments were selective to soybeans at the dosages and conditions tested. However, flumioxazin + imazethapyr was the most effective treatment.

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References
ADEGAS, F.S. *et al*. Glyphosate-resistant (GR) soybean and corn in Brazil: past, present, and future. *Adv. Weed Sci.,* v.40, p.e0202200102, 2022. doi.org/10.51694/AdvWeedSci/2022;40:seventy-five004

ALMEIDA, E.I.B. *et al.* Diversidade florística de plantas daninhas em lavouras de soja no cerrado do Maranhão, Brasil. *Cad. Pedag. (Lajeado),* v.21, p.1-20, 2024. doi: doi.org/10.54033/cadpedv21n8-074

ALMEIDA, J.G. *et al.* O Matopiba nas Chapadas Maranhenses: impactos da expansão do agronegócio na microrregião de Chapadinha. *Rev. Nera*, v.22, p.248-271, 2019. doi.org/10.47946/rnera.v0i47.6271

CARBONARI, C. A. Dynamics and efficacy of sulfentrazone, flumioxazin, and isoxaflutole herbicides applied on eucalyptus harvest residues. *NewForests*, v.51, p.723-37, 2019. doi.org/10.1007/s11056-019-09756-3

CARBONARI, C. A. *et al.* Dynamics of sulfentrazone applied to sugarcane crop residues. *Weed Sci.* v.64, p.201-206, 2016. doi.org/10.1614/WS-D-14-00171.1

EWRC - European Weed Research Council. Report of the 3rd, and 4th meetings of EWRC. *Comitte of methods in Weed Research*. *Weed Res.*, v. 4, p. 88, 1964.

FURTADO, J.A.L. *et al*. Uso de herbicidas residuais para o manejo de plantas daninhas tolerantes a glifosato no cerrado maranhense. *Rev. Cient. Multidisc. Núcleo Conhec.*, v.2, p.p.24-40, 2025. doi.org/10.32749/nucleodoconhecimento.com.br/agronomia/manejo-de-plantas

GAZOLA, T. *et al.* Selectivity and residual weed control of preemergentherbicides in soybean crop. *Rev. Ceres*, v.68, p.219-229, 2021. doi.org/10.1590/0034-737X202168030008

GONESE, J.U.; WEBER, J.B. Herbicide rate recommendations: soil parameter equations vs. registered rate recommendations. *Weed Technol.,* v.12, p.235-242, 1998. doi.org/10.1017/S0890037X00043748

INMET- Instituto Nacional de Meteorologia. (2021) Dados meteorológicos: temperatura média e precipitação, 2021. Brasília: INMET, 2021.

KALSING, A. *et al*. Efficacy of control of glyphosate-tolerant species of the Rubiaceae family

through double-knockdown applications. *Planta Daninha*, v.38, p.e020190700, 2020. doi.org/10.1590/S0100-83582020380100023

KHALIL, Y. *et al*. Rainfall affects leaching of preemergentherbicide from wheat residue into the soil. *PLOS ONE*, v.14, p.e021021, 2019. doi.org/10.1371/journal.pone.0210219

LORENZI, H. *et al. Manual de identificação e controle de plantas daninhas*. 2014.

OVEJERO, R.F.L *et al.* Residual herbicides in Roundup Ready soybean: a case study in multiple years and locations with Ipomoea triloba. *Cienc. Agrotecnol.* v.43, p.1-10, 2019.doi.org/10.1590/1413-7054201943000319

PASSOS, M.L.V.; Zambrzycki, G.C.; Pereira, R.S. Balanço hídrico e classificação climática para uma determinada região de Chapadinha-MA. *Rev. Bras. Agricul. Irrigada*, v.10, p.758-766, 2016. doi.org/10.7127/rbai.v10n400402

PONTE, I. S. *et al*. Aerial survey and glyphosate-resistant weeds control before soybean seeding. *Aust. J. Crop Sci.,* v.18, p.29–36, 2024. doi.org/ 10.21475/ajcs.24.18.01.p4019

SALOMÃO, H.M. *et al*. Weed management with pre-emergent herbicides in soybean crops. *Communications in Plant Sci.*, v.11, 2021. doi.org/10.26814/cps2021008

SANTOS, C.A.F. *et al*. Performance of lipophilic pre-emergence herbicides in no-till and conventional soybean cultivation systems. *Ensaios Ciênc.*, v. 29, p. 978-994, 2025. doi: https://doi.org/10.17921/1415-6938.2025v29n4p978-994

SANTOS, H. G. *et al*. *Sistema Brasileiro de Classificação de Solos.* Rio de Janeiro: Embrapa Solos, 2018.

SBCPD - Sociedade Brasileira da Ciência das Plantas Daninhas. *Procedimentos para instalação, avaliação e análise de experimentos com herbicidas*. Londrina: SBCPD, 1995.

SILVA, L.R.D *et al*. Glyphosate-Resistant Weeds Control with Double-Shooting in Soybean Pre-Planting. *Ensaios Ciência*, v.29, n.3, p.655-669, 2025. doi.org/10.17921/1415-6938.2025v29n3p655-669

SILVA, M.M. *et al*. Pre-emergence herbicides effects in no-till soybean system with panicum maximum "BRS Tamani." Aust. J. Crop Sci., v.18, p.21-28, 2024. doi/10.3316/informit.T202404140000420097681405 8

TAKANO, H.K. *et al.* Goosegrass resistant to glyphosate in Brazil. *Planta Daninha*, v.35, 2017. doi.org/10.1590/S0100-83582017350100013

VARGAS, L. *et al*. Low level resistance of goosegrass (*Eleusine indica*) to glyphosate in Rio Grande do Sul-Brazil. *Planta Daninha*, v.31, p.677-686, 2013. doi.org/10.1590/S0100-83582013000300019

VILLALBA, A. (2009). Resistência a herbicidas: Glifosato. *Cienc. Doc. Tecnol.*, v.39, p.169-186, 2009.