REMUNOM
ISSN 2178-6925

Received: 25/08/2026 - **Accepted:** 03/09/2026
Vol: 13.19
DOI: 10.66104/mxj9qk49
Pages: 1-35

EFICÁCIA E SELETIVIDADE DE HERBICIDAS RESIDUAIS APLICADOS EM PRÉ-EMERGÊNCIA DA SOJA PARA O CONTROLE DE *ELEUSINE INDICA* EM DOIS SOLOS COM CARACTERÍSTICAS EDÁFICAS CONTRASTANTES

EFFICACY AND SELECTIVITY OF RESIDUAL HERBICIDES APPLIED IN SOYBEAN PRE-EMERGENCE FOR *ELEUSINE INDICA* CONTROL UNDER TWO CONTRASTING SOIL CONDITIONS

EFICACIA Y SELECTIVIDAD DE HERBICIDAS RESIDUALES APLICADOS EN PREEMERGENCIA DE LA SOJA PARA EL CONTROL DE *ELEUSINE INDICA* EN DOS SUELOS CON CARACTERÍSTICAS EDÁFICAS CONTRASTANTES

Doctor Wilton Lessa Silva
Instituto Federal de Educação, Ciência e Tecnologia Goiano (IF Goiano), Urutaí, Goiás, Brasil.
E-mail: wilton@soloeplantaconsult.com
ORCID: https://orcid.org/0009-0006-3147-2758

Master Wilhan Valasco dos Santos
Instituto Federal de Educação, Ciência e Tecnologia Goiano (IF Goiano), Rio Verde, Brasil.
E-mail: wilhanvalasco@hotmail.com
ORCID: https://orcid.org/0000-0002-6533-2407
**Autor correspondente*

Master Walter Baida Garcia Coutinho
Departamento de Estatística, Universidade Federal de Viçosa (UFV), Viçosa, Minas Gerais, Brasil.
E-mail: walterbgc1@gmail.com
ORCID: https://orcid.org/0000-0002-9894-6122

Doctor Marco Antonio Moreira de Freitas
Instituto Federal de Educação, Ciência e Tecnologia Goiano (IF Goiano), Urutaí, Goiás, Brasil.
E-mail: marco.freitas@ifgoiano.edu.br
ORCID: https://orcid.org/0000-0001-6718-4906

CC BY

REMUNOM
ISSN 2178-6925

Received: 25/08/2026 - **Accepted:** 03/09/2026
Vol: 13.19
DOI: 10.66104/mxj9qk49
Pages: 1-35

Resumo

O capim-pé-de-galinha (*Eleusine indica*) é uma das plantas daninhas mais problemáticas nos sistemas brasileiros de produção de grãos, devido à sua elevada capacidade competitiva, intensa produção de sementes e crescente ocorrência de biótipos resistentes a herbicidas. Este estudo avaliou a eficácia de controle e a seletividade de herbicidas residuais aplicados em pré-emergência da soja em dois solos com características físico-químicas contrastantes. Foram conduzidos quatro ensaios de campo em Correntina, Bahia, Brasil, na safra 2018/2019: dois ensaios de eficácia de controle (Local 1 e Local 2) e dois ensaios de seletividade (Local 1 e Local 2). Os dados foram originalmente obtidos e documentados na dissertação de Silva (2020), depositada no Instituto Federal Goiano. Utilizou-se delineamento em blocos casualizados com quatro repetições. Nos ensaios de eficácia avaliaram-se dez tratamentos (oito herbicidas residuais, testemunha capinada e testemunha sem capina), em parcelas de 36 m² com área útil de 19,2 m². Nos ensaios de seletividade avaliaram-se nove tratamentos (os mesmos oito herbicidas e uma testemunha sem herbicida), em parcelas de 30 m² com área útil de 18 m², mantidas livres de plantas daninhas por capinas manuais. O controle de *E. indica* foi avaliado aos 14, 21, 28 e 35 dias após a aplicação (DAA) e a injúria à cultura aos 7, 14, 21 e 28 dias após a emergência (DAE). Cada ensaio foi analisado separadamente por análise de variância, teste de Dunnett, mapas de calor, agrupamento hierárquico e modelos de regressão. S-metolachlor, clomazone e trifluralin mantiveram os maiores níveis de controle aos 35 DAA (80,6–91,7% no Local 1 e 73,9–89,5% no Local 2) e não reduziram a produtividade nos ensaios de seletividade. Chlorimuron apresentou os menores níveis de controle (53,6% no Local 1 e 65,4% no Local 2, aos 35 DAA). Nos ensaios de eficácia, a ausência de controle reduziu a produtividade em 904,8 e 708,8 kg ha^{-1} nos Locais 1 e 2, respectivamente. Nos ensaios de seletividade, diclosulam, imazethapyr + flumioxazin e chlorimuron apresentaram as maiores injúrias visuais e as menores produtividades no Local 2, de textura arenosa. Como os dois locais diferiram simultaneamente em teor de argila, matéria orgânica, pH, CTC e saturação por bases, o desenho experimental não permite atribuir isoladamente ao teor de argila as diferenças observadas. Os resultados indicam que a escolha de herbicidas residuais deve considerar as condições edáficas locais, distinguindo as perdas associadas à interferência da planta daninha daquelas associadas à resposta da cultura ao herbicida.

Palavras-chave: competição de plantas daninhas; injúria à cultura; manejo químico; ambientes edáficos contrastantes; perda de produtividade.

Abstract

Goosegrass (*Eleusine indica*) is one of the most problematic weeds in Brazilian grain production systems due to its high competitive ability, intense seed production, and increasing occurrence of herbicide-resistant biotypes. This study evaluated the control efficacy and the selectivity of residual herbicides applied in soybean pre-emergence in two soils with contrasting physical and chemical characteristics. Four field trials were carried out in Correntina, Bahia, Brazil, during the 2018/2019 growing season: two control-efficacy trials (Site 1 and Site 2) and two selectivity trials (Site 1 and Site 2). The data were originally obtained and documented in the dissertation of Silva (2020), deposited at the Instituto Federal Goiano. A randomized complete block design with four replications was used. The efficacy trials comprised ten treatments (eight residual herbicides, a weeded control and an unweeded control), in 36 m² plots with a useful area of 19.2 m². The selectivity trials comprised nine treatments (the same eight herbicides and a control without herbicide), in 30 m² plots with a useful area of 18 m², all kept free of weeds by manual weeding. Control of *E. indica* was assessed at 14, 21, 28 and 35 days after application (DAA) and crop injury at 7, 14, 21 and 28 days after emergence (DAE). Each trial was analysed separately by analysis of variance, Dunnett's test, heatmaps, hierarchical clustering and regression models. S-metolachlor, clomazone and trifluralin maintained the highest control levels at 35 DAA (80.6–91.7% at Site 1 and 73.9–89.5% at Site 2) and did not reduce yield in the selectivity trials. Chlorimuron showed the lowest control levels (53.6% at Site 1 and 65.4% at Site 2 at 35 DAA). In the efficacy trials, the absence of weed control reduced grain yield by 904.8 and 708.8 kg ha^{-1} at Sites 1 and 2, respectively. In the selectivity trials, diclosulam, imazethapyr + flumioxazin and chlorimuron caused the highest visual injury and the lowest yields at Site 2, of sandy texture. Because the two sites differed simultaneously in clay content, organic matter, pH, cation exchange capacity and base saturation, the experimental design does not allow the observed

CC BY

REMUNOM
ISSN 2178-6925

Received: 25/08/2026 - **Accepted:** 03/09/2026
Vol: 13.19
DOI: 10.66104/mxj9qk49
Pages: 1-35

differences to be attributed to clay content alone. The results indicate that the choice of residual herbicides should consider local edaphic conditions, distinguishing losses associated with weed interference from those associated with the crop response to the herbicide.

Keywords: weed competition; crop injury; chemical management; contrasting edaphic environments; yield loss.

Resumen

La pata de gallina (*Eleusine indica*) es una de las malezas más problemáticas en los sistemas brasileños de producción de granos, debido a su elevada capacidad competitiva, intensa producción de semillas y creciente ocurrencia de biotipos resistentes a herbicidas. Este estudio evaluó la eficacia de control y la selectividad de herbicidas residuales aplicados en preemergencia de la soja en dos suelos con características físico-químicas contrastantes. Se realizaron cuatro ensayos de campo en Correntina, Bahía, Brasil, durante la campaña 2018/2019: dos ensayos de eficacia de control (Local 1 y Local 2) y dos ensayos de selectividad (Local 1 y Local 2). Los datos fueron obtenidos y documentados originalmente en la disertación de Silva (2020), depositada en el Instituto Federal Goiano. Se utilizó un diseño de bloques al azar con cuatro repeticiones. Los ensayos de eficacia incluyeron diez tratamientos (ocho herbicidas residuales, un testigo desmalezado y un testigo sin desmalezar), en parcelas de 36 m² con área útil de 19,2 m². Los ensayos de selectividad incluyeron nueve tratamientos (los mismos ocho herbicidas y un testigo sin herbicida), en parcelas de 30 m² con área útil de 18 m², mantenidas libres de malezas mediante carpidas manuales. El control de *E. indica* se evaluó a los 14, 21, 28 y 35 días después de la aplicación (DDA) y el daño al cultivo a los 7, 14, 21 y 28 días después de la emergencia (DDE). Cada ensayo fue analizado separadamente mediante análisis de varianza, prueba de Dunnett, mapas de calor, agrupamiento jerárquico y modelos de regresión. S-metolachlor, clomazone y trifluralin mantuvieron los mayores niveles de control a los 35 DDA (80,6–91,7% en el Local 1 y 73,9–89,5% en el Local 2) y no redujeron el rendimiento en los ensayos de selectividad. Chlorimuron presentó los menores niveles de control (53,6% en el Local 1 y 65,4% en el Local 2, a los 35 DDA). En los ensayos de eficacia, la ausencia de control redujo el rendimiento en 904,8 y 708,8 kg ha^{-1} en los Locales 1 y 2, respectivamente. En los ensayos de selectividad, diclosulam, imazethapyr + flumioxazin y chlorimuron presentaron los mayores daños visuales y los menores rendimientos en el Local 2, de textura arenosa. Como los dos locales difirieron simultáneamente en contenido de arcilla, materia orgánica, pH, CIC y saturación por bases, el diseño experimental no permite atribuir las diferencias observadas únicamente al contenido de arcilla. Los resultados indican que la elección de herbicidas residuales debe considerar las condiciones edáficas locales, distinguiendo las pérdidas asociadas a la interferencia de la maleza de aquellas asociadas a la respuesta del cultivo al herbicida.

Palabras clave: competencia de malezas; daño al cultivo; manejo químico; ambientes edáficos contrastantes; pérdida de rendimiento.

1. Introduction

Eleusine indica (L.) Gaertn., known as goosegrass, is an annual, self-pollinating weed with C_4-type photosynthetic metabolism, highly competitive, with low soil fertility requirements, and widely distributed in the main soybean-producing regions of Brazil. Its high adaptive capacity is reinforced by high seed production, which can exceed 120,000 per plant, and by seed dormancy, which ensures persistence in the soil seed bank (GARWOOD, 1989; KISSMANN, 2007; CHAUHAN; JOHNSON, 2008; TAKANO et al., 2016).

CC BY

REMUNOM
ISSN 2178-6925

Received: 25/08/2026 - **Accepted:** 03/09/2026
Vol: 13.19
DOI: 10.66104/mxj9qk49
Pages: 1-35

Chemical control has been the main method of managing the species; however, the continuous and inappropriate use of herbicides with the same mechanisms of action has favored the selection of biotypes resistant to at least eight different herbicide sites of action worldwide (HEAP, 2026; MA et al., 2019). Cases of resistance to glyphosate, glufosinate, paraquat, and acetyl-CoA carboxylase (ACCase) inhibitors have been widely documented (LEE; NGIM, 2000; KAUNDUN et al., 2008; MUELLER et al., 2011; CHEN et al., 2015; JALALUDIN et al., 2015; MCCULLOUGH et al., 2016). In Brazil, the consolidated records include resistance to ACCase inhibitors, to glyphosate (EPSPS) and multiple resistance involving these mechanisms (*BRAZ et al., 2025,* VIDAL et al., 2006; TAKANO et al., 2017; HEAP, 2026).

Factors such as frequency of use, persistence of herbicides in the environment, weed emergence pattern, and limited effectiveness of alternative methods to chemical control favor the development and spread of resistance (ROMAN et al., 2004; VENCILL et al., 2012; ULGUIM et al., 2013; HANSON et al., 2014). It is estimated that, even with the introduction of new mechanisms of action, there will be an increase of up to 60% in cases of resistance by 2050 (WESTWOOD et al., 2018), making the adoption of more sustainable management strategies essential (LAGATOR et al., 2013; GAGE et al., 2019).

In this scenario, the use of residual herbicides applied in pre-emergence has gained prominence in the management of E. indica. These products control the first flushes of weed emergence, reduce the seed bank, and decrease selection pressure for new cases of resistance (SOMERVILLE et al., 2017; BECKIE et al., 2019). In addition, by minimizing initial competition with the crop, pre-emergent herbicides provide a more efficient basis for post-emergence management (OLIVEIRA NETO et al., 2013; NUNES et al., 2018). As the time between the emergence of E. indica and the ideal stage for post-emergence control is short, due to its accelerated growth and early tillering (from 9 days after emergence), the use of pre-emergents becomes even more relevant (TAKANO et al., 2016).

Despite the advantages, the performance of residual herbicides varies according to their physicochemical properties, edaphoclimatic conditions, and

CC BY

REMUNOM
ISSN 2178-6925

Received: 25/08/2026 - **Accepted:** 03/09/2026
Vol: 13.19
DOI: 10.66104/mxj9qk49
Pages: 1-35

interaction with the soil, especially with regard to clay content, pH, and organic matter (CHRISTOFFOLETI et al., 2008; FREITAS et al., 2014; NORDMEYER, 2015). This interaction can influence both control efficacy and selectivity to the crop, which requires attention in the choice and use of these products (DUARY, 2008; VARANASI et al., 2016).

Selectivity, defined as the ability to control weeds without negatively affecting crop productivity, should not be evaluated solely by visual symptoms of phytotoxicity (NEGRISOLI et al., 2004). There are herbicides that, even without causing apparent injuries, significantly reduce soybean yield (OLIVEIRA JR.; INOUE, 2011; MONQUERO et al., 2011). Therefore, in addition to visual observations, it is essential to consider agronomic variables, such as crop growth and productivity.

Surveys carried out in the 2016/2017 season indicated the occurrence of *E. indica* in approximately 14 million hectares of Brazilian soybean areas, second only to the genus *Conyza* (CHAUHAN et al., 2017; LÚCIO et al., 2019). These figures should be read as a historical reference for that period, since updated national estimates of the proportion of infested soybean area are not available. In this context, the identification of effective residual herbicides for controlling this species, with proven selectivity to soybeans, is essential to expand the options for rotating mechanisms of action and reduce the impact of weeds on the crop.

Thus, this study aimed to evaluate the control efficacy of residual herbicides applied in pre-emergence on *Eleusine indica* and their selectivity to the soybean crop in two experimental environments with contrasting physical and chemical characteristics, distinguishing the effects associated with weed control from those directly related to the crop response to the herbicides. It should be noted that the resistance status of the *E. indica* populations present in the experimental areas was not determined; therefore, the results refer to the local populations, without any inference about their susceptibility or resistance to specific herbicide mechanisms of action.

2. Methodology

Origin of the data and contribution of the present study

CC BY

REMUNOM
ISSN 2178-6925

Received: 25/08/2026 - **Accepted:** 03/09/2026
Vol: 13.19
DOI: 10.66104/mxj9qk49
Pages: 1-35

The dataset analysed in this manuscript was obtained from four field trials carried out during the 2018/2019 growing season and originally documented in the dissertation of the first author (SILVA, 2020), deposited at the Instituto Federal de Educação, Ciência e Tecnologia Goiano. In that document, the two efficacy trials and the two selectivity trials were reported in separate chapters and analysed by multivariate analysis of variance followed by canonical discriminant analysis. The contribution of the present manuscript is a joint synthesis of the four trials, in which the primary results of control, injury and agronomic performance are presented together, the comparison of each treatment with the control appropriate to each experimental question is formalised by Dunnett's test, and the similarity patterns among treatments and between the two edaphic environments are described by exploratory multivariate tools (heatmaps and hierarchical clustering). No new field data were collected for this manuscript, and the original experimental structure of each trial was preserved in all analyses.

Characterization of the experimental areas

Four field trials were conducted between November 2018 and April 2019 in commercial soybean production areas in the municipality of Correntina, Bahia, Brazil, on dystrophic Red-Yellow Latosols, classified according to the edition of the Brazilian Soil Classification System in force at the time of the trials (SANTOS et al., 2013). Two trials evaluated the control efficacy of residual herbicides on Eleusine indica (efficacy trials) and two trials evaluated the selectivity of the same herbicides to soybean in the absence of weed competition (selectivity trials); in each set, one trial was installed at each of the two sites. The efficacy trials were installed at Fazenda Brasholanda (Site 1), at coordinates 13º46'57.03" S and 46º01'44.83" W, at an altitude of 910 m, and at Fazenda Boi Branco (Site 2), at coordinates 13º46'42.07" S and 46º01'53.19" W, at an average altitude of 860 m. The selectivity trials were installed in adjacent areas of the same farms (Site 1: 13º41'02.12" S and 45º51'08.51" W, 910 m; Site 2: 13º40'59.06" S and 45º51'20.87" W, 863 m). In both sets of trials, the straight-line distance between Site 1 and Site 2 was 23 km.

Both areas presented a homogeneous distribution of Eleusine indica plants and a history of infestation classified as medium to high, with evidence of a large

CC BY

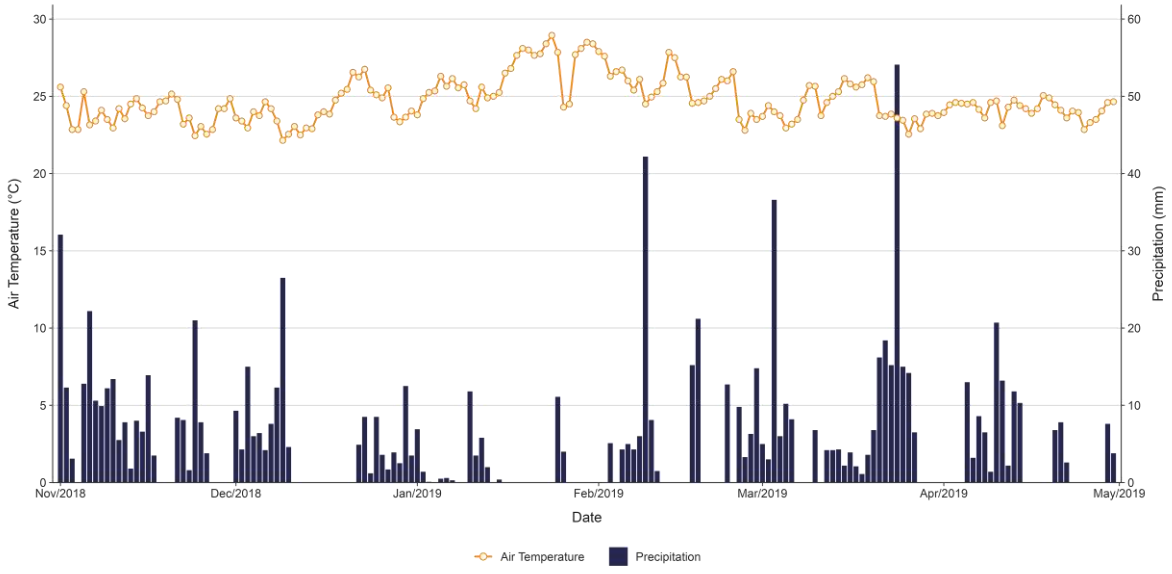
REMUNOM
ISSN 2178-6925

Received: 25/08/2026 - **Accepted:** 03/09/2026
Vol: 13.19
DOI: 10.66104/mxj9qk49
Pages: 1-35

soil seed bank; other weed species occurred naturally at very low density and frequency, mainly because of the competition imposed by E. indica. This classification is qualitative, since the infestation was not quantified as pre-treatment plant density (plants m^{-2}). Between April and October 2018, before the installation of the trials, the areas were kept fallow and two applications of 2,4-D (670 g a.e. ha^{-1}) were carried out, with the aim of controlling broadleaf weeds and preventing their seed production inside and around the experimental areas.

According to the Köppen climate classification, the region has a Cwa type climate (tropical highland), characterized by rainy summers and dry winters. The meteorological data regarding temperature and precipitation recorded during the experiments are presented in Figure 1.

Figure 1. Precipitation (mm) and average temperature (°C) that occurred during the conduct of the experiments.



Source: Adama Experimental Station, Brasholanda Farm, Correntina, BA.

Figure 1 characterizes the rainfall and mean air-temperature conditions recorded during the experimental period.

Before the installation of the experiments, soil samples were collected at a depth of 0–20 cm for physicochemical characterization (Table 1).

CC BY

REMUNOM
ISSN 2178-6925

Received: 25/08/2026 - **Accepted:** 03/09/2026
Vol: 13.19
DOI: 10.66104/mxj9qk49
Pages: 1-35

Table 1. Physical-chemical characteristics of the soil in each experimental area (0-20 cm). Correntina, BA, 2018/2019.

Site	Particle size analysis (%)			pH	MO	CTC ef	V
	Clay	Silte	Sand	$CaCl_2$	g dm^{-3}	cmolc dm^{-3}	%
1 Faz. Brasholanda	21,60	5,40	73,00	6.32	20.60	52.57	84.02
2 Faz. Boi Branco	12,50	3,10	84,40	5.54	14.04	33.66	60.47

Source: Research data.

According to the textural grouping criteria adopted in Brazil, Site 1 (216 g kg^{-1} of clay) corresponds to a medium-textured soil, whereas Site 2 (125 g kg^{-1} of clay and 844 g kg^{-1} of sand) corresponds to a sandy-textured soil. Besides clay content, the two sites differed simultaneously in sand content, organic matter, pH, effective cation exchange capacity and base saturation (Table 1). Site and soil attributes are therefore confounded in this study, and the responses observed cannot be attributed to clay content in isolation.

Soybean crop establishment and management

In all four trials, two pre-sowing desiccation applications were carried out: the first 18 days before sowing (DBS), with glyphosate (1,440 g ha^{-1}) + clethodim (192 g ha^{-1}), and the second one day before sowing, with paraquat (240 g ha^{-1}). This desiccation programme describes the protocol adopted in the 2018/2019 season and is reported here only for historical and reproducibility purposes; it does not represent a current agronomic recommendation, in view of the subsequent regulatory changes concerning paraquat in Brazil. In the efficacy trials, glyphosate (2,160 g ha^{-1}) was additionally applied at 30 days after crop emergence (DAE), in order to control later flushes of weed emergence. In the selectivity trials, no post-emergence herbicide was applied; instead, all experimental units, including the control, were kept free of weeds throughout the crop cycle by manual weeding, so as to eliminate the effect of weed competition on the crop response. Phytosanitary management with insecticides and fungicides was carried out according to the technical recommendations for soybean cultivation in the region.

The preparation of the areas was carried out using a conventional planting system. Soybean sowing was performed mechanically using the Monsoy 8349

CC BY

REMUNOM
ISSN 2178-6925

Received: 25/08/2026 - **Accepted:** 03/09/2026
Vol: 13.19
DOI: 10.66104/mxj9qk49
Pages: 1-35

IPRO cultivar, with a cycle of approximately 125 days and a population of 180,000 plants ha^{-1}, spaced in rows of 0.6 m. The seeds were treated with thiamethoxam, pyraclostrobin + thiophanate-methyl + fipronil, carbendazim + thiram, and inoculated with Bradyrhizobium japonicum (strains SEMIA 5079 and 5080).

In the efficacy trials, sowing was carried out on 13 November 2018 at Site 1, with seedling emergence on 19 November 2018, and on 16 November 2018 at Site 2, with emergence on 23 November 2018. The selectivity trials were sown later: on 20 November 2018 at Site 1, with emergence on 26 November 2018, and on 22 November 2018 at Site 2, with emergence on 29 November 2018. In all trials, base fertilization consisted of 200 kg ha^{-1} of triple superphosphate applied in the planting furrow, and topdressing was carried out at 25 DAE with 150 kg ha^{-1} of potassium chloride.

Experimental Design and Treatments

All four trials followed a randomized complete block design with four replications, and the same eight residual herbicides and doses were evaluated in every trial (Table 2). The two sets of trials differed, however, in the number of treatments, in the controls adopted and in plot dimensions, according to their specific objectives. In the efficacy trials, ten treatments were evaluated: eight residual herbicides applied in pre-emergence, one weeded control and one unweeded control. In the selectivity trials, nine treatments were evaluated: the same eight residual herbicides and one control without herbicide; in this set, all plots, including the control, were kept free of weeds by manual weeding, so that the crop response could be assessed in the absence of weed interference.

Table 2. Herbicides and doses used in spraying for the control of goosegrass (Eleusine indica) in pre-emergence of soybeans. Correntina, BA, 2018/2019.

N°	Treatments*	Formulation**	Concentration	Dose	HRAC group (2026)
			(g de i.a L^{-1} ou kg^{-1})	(g e.a ou i.a. ha^{-1})	site of action†
1	Control without weeding	-	-	-	–
2	Weeded control	-	-	-	–

CC BY

REMUNOM
ISSN 2178-6925

Received: 25/08/2026 - **Accepted:** 03/09/2026
Vol: 13.19
DOI: 10.66104/mxj9qk49
Pages: 1-35

N°	Treatments*	Formulation**	Concentration (g de i.a L^{-1} ou kg^{-1})	Dose (g e.a ou i.a. ha^{-1})	HRAC group (2026) site of action†
3	Trifluralin	EC	600	1200	3 (microtubule assembly inhibitor)
4	S-metolachlor	EC	960	960	15 (VLCFA inhibitor)
5	Diclosulam	WG	840	29,4	2 (ALS inhibitor)
6	Imazethapyr + Flumioxazin	SC	200 + 100	100 + 50	2 + 14 (ALS + PPO inhibitors)
7	Sulfentrazone	SC	500	150	14 (PPO inhibitor)
8	Sulfentrazone + Diuron	SC	175 + 300	140 + 280	14 + 5 (PPO + PSII inhibitors)
9	Clomazone	EC	800	800	13 (DOXP synthase inhibitor)
10	Chlorimuron-ethyl	WG	250	20	2 (ALS inhibitor)

For all herbicides, the adjuvant recommended by the respective manufacturer was added. Since the recommended adjuvant varies between manufacturers and formulations, the original documentation records this practice in a non-prescriptive form, without specifying a single commercial product or concentration. EC: emulsifiable concentrate; WG: water-dispersible granules; SC: suspension concentrate. † Herbicide group and site of action according to the global classification of the Herbicide Resistance Action Committee (HRAC). The same herbicides and doses were used in the efficacy and in the selectivity trials; the weeded and unweeded controls belong to the efficacy trials, and the control without herbicide to the selectivity trials.

In the efficacy trials, each experimental unit consisted of 10 soybean rows (6 m wide × 6 m long = 36 m² of total area), with a useful area of 19.2 m² considered for the evaluations. In the selectivity trials, each experimental unit consisted of 10 soybean rows (6 m wide × 5 m long = 30 m² of total area), with a useful area of 18 m².

Treatment Application

Herbicide applications were carried out immediately after sowing and before the emergence of soybean and of E. indica, a practice locally known as "plante-aplique" (plant-and-spray), using a CO_2-pressurized backpack sprayer at 2.2 kg cm^{-2}, with a spray volume of 150 L ha^{-1}. The spray boom contained six XR 110.02 flat-fan nozzles spaced 0.5 m apart. In all trials, applications were made to slightly moist soil. Accumulated rainfall in the first seven days after application differed between the two sets of trials: 45 mm in the efficacy trials and 20 mm in the selectivity trials. Since the availability of pre-emergence herbicides depends strongly on soil moisture and on incorporation by rainfall, this difference must be

CC BY

REMUNOM
ISSN 2178-6925

Received: 25/08/2026 - **Accepted:** 03/09/2026
Vol: 13.19
DOI: 10.66104/mxj9qk49
Pages: 1-35

taken into account when comparing the two sets of trials. The environmental conditions recorded during the applications are presented in Table 3, for the efficacy trials, and in Table 4, for the selectivity trials.

Table 3. Climatic conditions recorded during the applications of the treatments in the efficacy trials, carried out on the day of soybean sowing. Correntina, BA, 2018/2019.

Site	Temperature	Relative humidity	Wind Speed
	°C	%	km h^{-1}
1 Faz. Brasholanda	26,6	82,4	3,4
2 Faz. Boi Branco	27,1	78,8	3,1

Source: Research data.

In the efficacy trials, the environmental conditions were similar between the two sites, with temperatures of 26.6–27.1 °C, relative humidity of 78.8–82.4% and wind speeds of 3.1–3.4 km h^{-1}.

Table 4. Climatic conditions recorded during the applications of the treatments in the selectivity trials, carried out on the day of soybean sowing. Correntina, BA, 2018/2019.

Site	Temperature	Relative humidity	Wind speed
	°C	%	km h^{-1}
1 Faz. Brasholanda	28.1	75.0	2.9
2 Faz. Boi Branco	26.9	74.3	3.3

Source: SILVA (2020).

In the selectivity trials, temperatures ranged from 26.9 to 28.1 °C, relative humidity from 74.3 to 75.0% and wind speeds from 2.9 to 3.3 km h^{-1}.

Variables evaluated

In the efficacy trials, the control of E. indica was visually assessed at 14, 21, 28 and 35 days after application (DAA), using a percentage scale (0% = no control; 100% = death of all plants), according to ALAM (1974). In the selectivity trials, visual injury to soybean plants was assessed at 7, 14, 21 and 28 days after crop emergence (DAE) using two complementary scales: the percentage scale of ALAM (1974), which quantifies the proportion of affected plant tissue and is the form in which the data are reported in Table 6, and the ordinal scale of the European Weed

CC BY

REMUNOM
ISSN 2178-6925

Received: 25/08/2026 - **Accepted:** 03/09/2026
Vol: 13.19
DOI: 10.66104/mxj9qk49
Pages: 1-35

Research Council (EWRC, 1964), ranging from note 1 (absence of symptoms) to note 9 (death of 100% of the plants), used to classify the severity of the symptoms observed. Because control was assessed in days after application and injury in days after emergence, the two sets of evaluation dates are not directly comparable.

The agronomic variables of soybeans included:

a) Plant stand (PS): count in two 2-meter samples in the three central rows of the useful area, at 20 DAE;

b) Plant height (PH): measured from the ground to the last node of the main stem at the R1 stage;

c) Shoot dry mass (DM): 10 plants per plot dried at 65ºC for 72 h;

d) Number of pods per plant (NVP): count on 10 plants;

e) Number of grains per plant (NGP): obtained by averaging the grains per plant;

f) Thousand-grain weight (PMG): average of eight subsamples of 100 grains;

g) Productivity (PG): harvest of 12 m², converted to kg ha^{-1}, with standardized moisture at 13%.

Statistical analysis

The four trials were analysed separately. Each trial had its own experimental structure: a different number of treatments (ten in the efficacy trials and nine in the selectivity trials), different controls (weeded and unweeded controls versus a weed-free control without herbicide), different plot dimensions (36 and 30 m²), different sowing and emergence dates, different accumulated rainfall in the seven days after application (45 and 20 mm) and different weed management regimes (post-emergence glyphosate versus manual weeding). The four datasets therefore do not constitute repetitions of a single experiment and were not pooled into a single factorial model. The possibility of a joint analysis of the factors was considered at the exploratory stage; however, in addition to the structural differences described above, the combined model containing the treatment × site interaction did not satisfactorily meet the assumptions required for valid parametric inference. Consequently, the analysis of each experiment separately was adopted, a decision determined by the structure and the behaviour of the data and not by the search for

CC BY

REMUNOM
ISSN 2178-6925

Received: 25/08/2026 - **Accepted:** 03/09/2026
Vol: 13.19
DOI: 10.66104/mxj9qk49
Pages: 1-35

statistically significant results. This strategy preserved the experimental structure of each trial and allowed the behaviour of the treatments to be evaluated adequately within each environment. Site was interpreted as a fixed factor, since the two areas were specifically selected for their contrasting physical and chemical characteristics and do not constitute a random sample of the soils or of the production environments of the region; accordingly, the comparison between sites is presented as a descriptive and exploratory contrast, and not as a formal test of the site effect.

Within each trial, the data were evaluated for the assumptions of analysis of variance (ANOVA): the normality of the residuals was verified by the Shapiro-Wilk test and the homogeneity of variances by the Bartlett test. Once these conditions were met, the treatments were compared with the control by Dunnett's test at $\alpha = 0.10$, the level adopted in the original analysis and used consistently throughout this manuscript. The control used in each comparison corresponded to the question being addressed: in the efficacy trials, the treatments were compared with the weeded control, so that the reduction in yield expresses the residual interference of E. indica under the management system adopted; in the selectivity trials, the treatments were compared with the weed-free control without herbicide, so that any reduction in yield expresses the response of the crop to the herbicide in the absence of weed competition.

To describe similarity relationships between herbicides and the evaluated variables (control and injury), heatmaps were constructed individually for each experiment, as well as a combined representation of the four datasets. These analyses are exploratory and descriptive: they summarise the proximity between response profiles and do not constitute significance tests, nor do they identify which edaphic attribute is responsible for any separation observed. The data used were the treatment means of each dataset, previously standardised by z-score within each dataset, in order to remove the effect of the different scales and units of the variables and to give all variables the same weight in the analysis. Euclidean distance was adopted as a dissimilarity metric, and the Ward.D2 clustering method was used to generate the dendrograms. The graphical representation was created with a continuous color scale, ranging from yellow (negative values) to blue (positive

CC BY

REMUNOM
ISSN 2178-6925

Received: 25/08/2026 - **Accepted:** 03/09/2026
Vol: 13.19
DOI: 10.66104/mxj9qk49
Pages: 1-35

values), using the pheatmap package (KOLDE, 2019).

Subsequently, a hierarchical cluster analysis was performed on the productive and biometric variables, aiming to describe the similarity between the pre-emergence herbicides within each experimental environment. Euclidean distance was again adopted as a similarity criterion, and the dendrograms were visualised using graphs generated with the ggplot2 package (WICKHAM, 2016). As with the heatmaps, these groupings are descriptive: the formation of clusters indicates proximity between response profiles and should not be interpreted as evidence of statistical difference between treatments, nor as a causal relationship with any specific soil attribute.

Finally, the control and injury data were fitted to linear and polynomial regression models as a function of the evaluation dates, in order to describe the temporal trend of the responses, with the choice of model based on the R^2 goodness-of-fit criterion. The models were fitted to the treatment means presented in Tables 5 and 6, and the resulting equations and coefficients of determination are given in Tables 9 and 10. Since each variable has only four evaluation dates, the quadratic model retains a single residual degree of freedom and selection by R^2 systematically favours it over the linear model; the adjusted coefficient of determination is therefore also reported, and the fitted models are used only as an exploratory, post-hoc description of the temporal behaviour of the treatments, and not as a confirmatory analysis or as support for inferences about differences between treatments or between sites.

In order to summarise the two experimental questions jointly, the treatments were also positioned in an efficacy × selectivity matrix (Figure 5), built for each site from the primary results of the two corresponding trials. The efficacy axis is the control of E. indica at 35 DAA, the most demanding evaluation date, with the threshold set at 80%, the level conventionally adopted as the minimum acceptable for chemical weed control. The selectivity axis is the grain yield of the selectivity trial expressed as a percentage of the weed-free control without herbicide, with the threshold set at 95%, which corresponds to the criterion of up to 5% yield reduction adopted as acceptable for residual herbicides in the primary source of the dataset.

CC BY

REMUNOM
ISSN 2178-6925

Received: 25/08/2026 - **Accepted:** 03/09/2026
Vol: 13.19
DOI: 10.66104/mxj9qk49
Pages: 1-35

Because the two axes come from different trials — installed in adjacent areas, with different sowing dates and different accumulated rainfall after application — the matrix is a descriptive synthesis of the four experiments and not a joint statistical analysis.

All analyses were performed in the R statistical computing environment version 4.4.3 (R CORE TEAM, 2025).

3. Results and Discussion

The primary results of the four trials are presented before the exploratory multivariate analyses. Table 5 shows the control of E. indica in the efficacy trials; Table 6, the visual injury to soybean in the selectivity trials; and Tables 7 and 8, the agronomic components and the absolute grain yield of the efficacy and selectivity trials, respectively. All values correspond to the treatment means documented in the primary source of the dataset (SILVA, 2020) and are reproduced with the same number of decimal places as in that source.

In both efficacy trials, S-metolachlor, clomazone and trifluralin maintained the highest levels of control throughout the evaluation period. At 35 DAA, the control provided by S-metolachlor reached 91.7% at Site 1 and 89.5% at Site 2, followed by clomazone (81.4% and 81.5%) and trifluralin (80.6% and 73.9%). Chlorimuron showed the lowest levels of control, decreasing from 71.5% at 14 DAA to 53.6% at 35 DAA at Site 1, and from 75.1% to 65.4% at Site 2. Diclosulam, sulfentrazone and sulfentrazone + diuron presented intermediate control, with values between 60.1% and 77.3% at 35 DAA (Table 5).

Table 5. Control of goosegrass (*Eleusine indica*) after application of pre-emergence herbicides in the efficacy trials, at two sites. Correntina, BA, 2018/2019.

Treatment	Dose	14 DAA	21 DAA	28 DAA	35 DAA
	(g a.e. or a.i. ha^{-1})	(%)	(%)	(%)	(%)
Site 1 – Faz. Brasholanda (medium texture)					
1 Unweeded control	–	0.0	0.0	0.0	0.0
2 Weeded control	–	100.0	100.0	100.0	100.0
3 Trifluralin	1200	91.4	88.4	81.4	80.6
4 S-metolachlor	960	94.1	95.0	94.0	91.7

CC BY

REMUNOM
ISSN 2178-6925

Received: 25/08/2026 - **Accepted:** 03/09/2026
Vol: 13.19
DOI: 10.66104/mxj9qk49
Pages: 1-35

Treatment	Dose	14 DAA	21 DAA	28 DAA	35 DAA
	(g a.e. or a.i. ha⁻¹)	(%)	(%)	(%)	(%)
5 Diclosulam	29.4	70.6	75.4	72.6	66.8
6 Imazethapyr + flumioxazin	100 + 50	82.8	76.5	73.4	69.6
7 Sulfentrazone	150	73.5	70.9	65.9	60.1
8 Sulfentrazone + diuron	140 + 280	79.4	75.0	69.7	66.6
9 Clomazone	800	92.6	91.1	88.0	81.4
10 Chlorimuron-ethyl	20	71.5	61.3	58.8	53.6
Site 2 – Faz. Boi Branco (sandy texture)					
1 Unweeded control	–	0.0	0.0	0.0	0.0
2 Weeded control	–	100.0	100.0	100.0	100.0
3 Trifluralin	1200	90.2	84.0	81.5	73.9
4 S-metolachlor	960	94.8	93.4	92.7	89.5
5 Diclosulam	29.4	80.0	82.3	77.1	71.9
6 Imazethapyr + flumioxazin	100 + 50	88.1	83.5	81.9	80.0
7 Sulfentrazone	150	83.8	80.0	77.3	72.6
8 Sulfentrazone + diuron	140 + 280	86.3	85.9	79.6	73.3
9 Clomazone	800	93.8	90.0	86.3	81.5
10 Chlorimuron-ethyl	20	75.1	74.1	70.5	65.4

Source: SILVA (2020). DAA: days after application.

In the selectivity trials, the visual injury symptoms caused by trifluralin, S-metolachlor, sulfentrazone, sulfentrazone + diuron and clomazone were transient: they were most evident at 7 DAE and were no longer detected from 21 DAE at Site 1 and from 28 DAE at Site 2. Diclosulam, imazethapyr + flumioxazin and chlorimuron caused the highest injury values, and the magnitude of these symptoms was markedly higher at Site 2, where injury increased up to 21 DAE and remained high at 28 DAE (44.50%, 52.50% and 48.00%, respectively), whereas at Site 1 the same treatments did not exceed 22.3% (Table 6).

Table 6. Visual injury to soybean plants (cultivar Monsoy 8349 IPRO) after application of pre-emergence herbicides in the selectivity trials, at two sites. Correntina, BA, 2018/2019.

Treatment	Dose	7 DAE	14 DAE	21 DAE	28 DAE
	(g a.i. ha⁻¹)	(%)	(%)	(%)	(%)
Site 1 – Faz. Brasholanda (medium texture)					
1 Control without herbicide	–	0.0	0.0	0.0	0.0
2 Trifluralin	1200	3.3	0.0	0.0	0.0
3 S-metolachlor	960	3.0	0.0	0.0	0.0
4 Diclosulam	29.4	12.5	20.0	22.3	16.3

CC BY

REMUNOM
ISSN 2178-6925

Received: 25/08/2026 - **Accepted:** 03/09/2026
Vol: 13.19
DOI: 10.66104/mxj9qk49
Pages: 1-35

Treatment	Dose	7 DAE	14 DAE	21 DAE	28 DAE
	(g a.i. ha⁻¹)	(%)	(%)	(%)	(%)
5 Imazethapyr + flumioxazin	100 + 50	11.3	15.5	15.0	11.5
6 Sulfentrazone	150	3.5	0.0	0.0	0.0
7 Sulfentrazone + diuron	140 + 280	7.0	4.3	0.0	0.0
8 Clomazone	800	7.0	3.0	0.0	0.0
9 Chlorimuron-ethyl	20	12.5	16.0	20.0	14.5
Site 2 – Faz. Boi Branco (sandy texture)					
1 Control without herbicide	–	0.00	0.00	0.00	0.00
2 Trifluralin	1200	14.50	13.25	4.00	0.00
3 S-metolachlor	960	11.25	8.00	3.00	0.00
4 Diclosulam	29.4	23.25	32.00	52.50	44.50
5 Imazethapyr + flumioxazin	100 + 50	24.25	36.50	55.00	52.50
6 Sulfentrazone	150	15.00	11.50	4.25	0.00
7 Sulfentrazone + diuron	140 + 280	20.25	21.00	11.00	0.00
8 Clomazone	800	16.25	12.00	3.50	0.00
9 Chlorimuron-ethyl	20	22.00	37.75	52.25	48.00

Source: SILVA (2020). DAE: days after emergence. Injury quantified as the percentage of affected plant tissue according to the scale of ALAM (1974); the severity of the symptoms was classified according to the ordinal scale of EWRC (1964), from note 1 (absence of symptoms) to note 9 (death of 100% of the plants).

In the efficacy trials, the absence of weed control reduced grain yield from 4833.1 to 3928.3 kg ha⁻¹ at Site 1 (a reduction of 904.8 kg ha⁻¹) and from 3248.1 to 2539.3 kg ha⁻¹ at Site 2 (708.8 kg ha⁻¹), confirming the high interference potential of the species. The highest yields were obtained with S-metolachlor, clomazone and trifluralin at both sites, and the lowest with chlorimuron (4227.5 kg ha⁻¹ at Site 1 and 2750.7 kg ha⁻¹ at Site 2). It should be emphasised that, in these trials, glyphosate was applied at 30 DAE; the final yield therefore expresses the result of the management system as a whole, that is, the residual pre-emergence treatment plus the post-emergence intervention, and not the isolated effect of the pre-emergence herbicide throughout the entire crop cycle (Table 7).

Table 7. Agronomic components and grain yield of soybean in the efficacy trials, as a function of the application of pre-emergence herbicides for the control of *Eleusine indica*, at two sites. Correntina, BA, 2018/2019.

CC BY

REMUNOM
ISSN 2178-6925

Received: 25/08/2026 - **Accepted:** 03/09/2026
Vol: 13.19
DOI: 10.66104/mxj9qk49
Pages: 1-35

Treatment	Stand (plants m⁻¹)	Height (cm)	Shoot DM (g plant⁻¹)	Pods (plant⁻¹)	Grains (plant⁻¹)	TGW (g)	Grain yield (kg ha⁻¹)
Site 1 – Faz. Brasholanda (medium texture)							
1 Unweeded control	10.5	56.9	11.2	68.4	151.4	137.8	3928.3
2 Weeded control	10.1	59.0	14.9	78.7	186.4	149.0	4833.1
3 Trifluralin	10.6	58.5	14.2	71.6	165.4	146.6	4631.3
4 S-metolachlor	10.6	59.2	15.0	78.4	184.5	147.3	4713.5
5 Diclosulam	10.5	50.1	12.1	69.1	165.3	152.5	4465.6
6 Imazethapyr + flumioxazin	10.2	57.4	13.8	74.9	170.4	144.5	4532.7
7 Sulfentrazone	11.2	58.8	14.0	72.9	168.3	148.0	4402.5
8 Sulfentrazone + diuron	10.4	57.4	14.2	70.2	165.7	146.1	4315.2
9 Clomazone	10.7	59.2	14.5	75.1	174.3	150.9	4726.9
10 Chlorimuron-ethyl	10.4	53.2	13.1	70.1	160.7	144.5	4227.5
Site 2 – Faz. Boi Branco (sandy texture)							
1 Unweeded control	10.6	44.9	8.1	44.5	104.9	125.7	2539.3
2 Weeded control	10.7	47.6	11.0	53.4	130.8	139.1	3248.1
3 Trifluralin	10.3	47.8	10.9	51.2	123.2	139.5	3092.3
4 S-metolachlor	10.6	48.1	10.7	53.4	128.3	134.5	3274.2
5 Diclosulam	11.1	40.8	10.1	50.6	126.4	124.3	2980.1
6 Imazethapyr + flumioxazin	11.5	38.5	9.6	49.8	117.3	123.5	2878.2
7 Sulfentrazone	11.0	48.6	10.7	49.3	121.1	133.5	3047.4
8 Sulfentrazone + diuron	9.6	45.9	9.7	48.6	116.9	132.7	3009.7
9 Clomazone	9.9	47.6	11.0	53.9	132.7	135.2	3166.6
10 Chlorimuron-ethyl	11.0	39.3	8.0	49.8	119.1	123.8	2750.7

Source: SILVA (2020). Shoot DM: shoot dry mass; TGW: thousand-grain weight. In this set of trials, glyphosate was applied at 30 days after emergence in all plots.

In the selectivity trials, conducted without weed competition, all treatments at Site 1 produced grain yields similar to that of the control without herbicide (4855.2 kg ha⁻¹), with reductions of less than 5%, even though diclosulam, imazethapyr + flumioxazin and chlorimuron reduced plant height and shoot dry mass. At Site 2, the yields obtained with imazethapyr + flumioxazin (2904.2 kg ha⁻¹), chlorimuron (3152.7 kg ha⁻¹), diclosulam (3195.8 kg ha⁻¹) and sulfentrazone + diuron (3232.4 kg ha⁻¹) were lower than that of the control (3430.2 kg ha⁻¹), whereas trifluralin, S-metolachlor, sulfentrazone and clomazone maintained yields equal to or higher than that of the control (Table 8).

CC BY

REMUNOM
ISSN 2178-6925

Received: 25/08/2026 - **Accepted:** 03/09/2026
Vol: 13.19
DOI: 10.66104/mxj9qk49
Pages: 1-35

Table 8. Agronomic components and grain yield of soybean (cultivar Monsoy 8349 IPRO) in the selectivity trials, as a function of the application of pre-emergence herbicides, at two sites. Correntina, BA, 2018/2019.

Treatment	Stand (plants m^{-1})	Height (cm)	Shoot DM (g $plant^{-1}$)	Pods ($plant^{-1}$)	Grains ($plant^{-1}$)	TGW (g)	Grain yield (kg ha^{-1})
Site 1 – Faz. Brasholanda (medium texture)							
1 Control without herbicide	10.8	61.5	14.7	78.3	190.4	148.7	4855.2
2 Trifluralin	10.2	63.1	14.7	77.6	187.8	148.4	4787.5
3 S-metolachlor	10.6	60.5	14.4	79.4	193.0	151.0	4829.2
4 Diclosulam	10.6	48.1	11.2	80.5	199.7	147.0	4876.0
5 Imazethapyr + flumioxazin	10.1	55.3	14.7	77.6	188.1	146.0	5029.6
6 Sulfentrazone	10.8	60.5	14.5	76.5	186.1	146.8	5047.9
7 Sulfentrazone + diuron	10.3	57.8	14.1	79.4	193.7	148.4	4834.4
8 Clomazone	10.8	61.1	13.6	79.4	195.2	147.6	4870.8
9 Chlorimuron-ethyl	10.4	56.1	12.9	76.8	183.5	146.8	4693.8
Site 2 – Faz. Boi Branco (sandy texture)							
1 Control without herbicide	11.1	52.5	12.9	59.3	145.7	141.3	3430.2
2 Trifluralin	10.6	50.4	10.6	59.3	144.3	138.6	3638.5
3 S-metolachlor	10.7	49.1	11.3	59.3	142.4	138.7	3558.8
4 Diclosulam	10.4	38.9	9.0	59.3	140.3	131.1	3195.8
5 Imazethapyr + flumioxazin	10.4	37.1	9.3	56.1	129.7	126.6	2904.2
6 Sulfentrazone	11.0	49.0	12.0	52.9	128.6	141.0	3451.0
7 Sulfentrazone + diuron	10.7	46.5	10.5	56.3	135.2	133.1	3232.4
8 Clomazone	10.7	50.5	10.8	58.4	141.1	139.0	3628.1
9 Chlorimuron-ethyl	10.2	35.3	8.7	55.4	131.9	127.3	3152.7

Source: SILVA (2020). Shoot DM: shoot dry mass; TGW: thousand-grain weight. In this set of trials, all plots were kept free of weeds by manual weeding throughout the crop cycle.

The analysis of yield loss in relation to the control appropriate to each experimental question revealed significant differences between treatments, both in the efficacy trials, in which the reference is the weeded control, and in the selectivity trials, in which the reference is the weed-free control without herbicide (Figure 2).

CC BY

REMUNOM
ISSN 2178-6925

Received: 25/08/2026 - **Accepted:** 03/09/2026
Vol: 13.19
DOI: 10.66104/mxj9qk49
Pages: 1-35

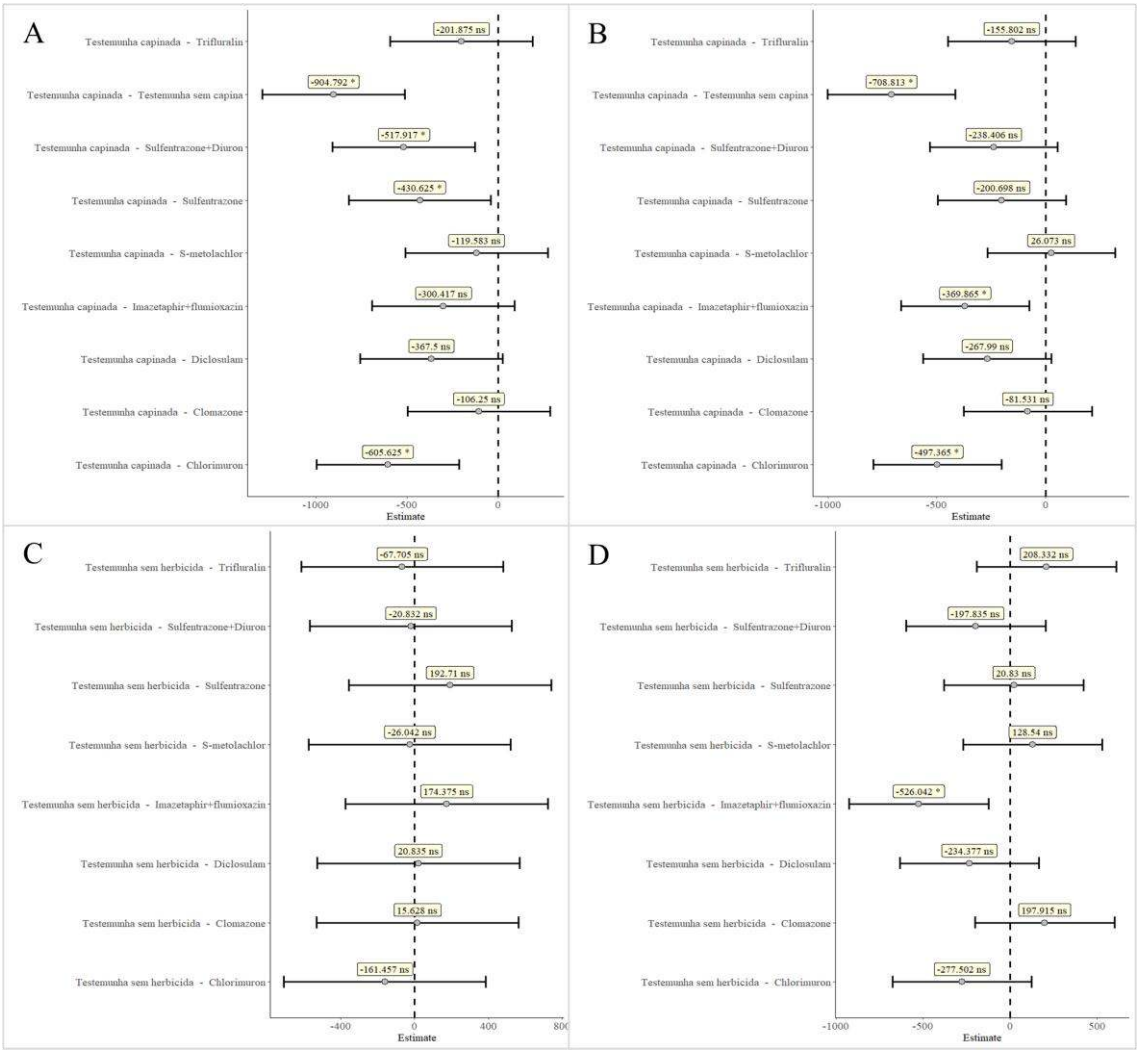


Figure 2. Yield loss in relation to the control adopted in each experimental question. A – Efficacy trial, Site 1 (medium texture); B – Efficacy trial, Site 2 (sandy texture); C – Selectivity trial, Site 1 (medium texture); D – Selectivity trial, Site 2 (sandy texture). In A and B, the treatments were compared with the weeded control; in C and D, with the weed-free control without herbicide. *Comparisons performed using Dunnett's test at α = 0.10.*

Source: Research data.

In the efficacy trials, the unweeded control and chlorimuron resulted in significant yield losses relative to the weeded control at both sites. At Site 1, sulfentrazone and sulfentrazone + diuron and, at Site 2, imazethapyr + flumioxazin were also associated with greater reductions in yield. The absence of weeding promoted losses exceeding 700 kg ha^{-1}, highlighting the high interference of the

CC BY

REMUNOM
ISSN 2178-6925

Received: 25/08/2026 - **Accepted:** 03/09/2026
Vol: 13.19
DOI: 10.66104/mxj9qk49
Pages: 1-35

weed, as already observed in field and greenhouse studies with residual herbicides (PROCÓPIO et al., 2001; PEREIRA et al., 2000). In this set of trials, the yield reduction associated with a treatment expresses mainly the residual interference of E. indica that was not controlled by the pre-emergence herbicide, and not necessarily an injurious effect of the herbicide on the crop: chlorimuron, for example, combined the lowest levels of control (Table 5) with the lowest yields (Table 7), a pattern compatible with weed interference rather than with a loss of selectivity.

In the selectivity trials, conducted in the absence of weed competition, none of the herbicides applied at Site 1 differed statistically from the control without herbicide, indicating adequate selectivity under those conditions. At Site 2, imazethapyr + flumioxazin showed a significant reduction in yield even without competition from weeds, a result consistent with the higher visual injury recorded in that environment (Table 6) and therefore attributable to the response of the crop to the herbicide. This difference between environments is compatible with the reported influence of soil attributes on the availability and selectivity of pre-emergence herbicides (KARPINSKI et al., 2014; AMIM et al., 2014), and suggests greater caution in soils with lower adsorption capacity, in which herbicides tend to show greater mobility and availability in the soil solution. It should be noted, however, that the two sites differed simultaneously in several physical and chemical attributes, and that the selectivity trials received less accumulated rainfall in the seven days after application than the efficacy trials (20 versus 45 mm); the responses observed cannot therefore be attributed exclusively to soil texture.

The exploratory analysis using heatmaps described distinct patterns of similarity between the treatments with pre-emergence herbicides and the controls, considering the productive and biometric variables (Figure 3).

CC BY

REMUNOM
ISSN 2178-6925

Received: 25/08/2026 - **Accepted:** 03/09/2026
Vol: 13.19
DOI: 10.66104/mxj9qk49
Pages: 1-35

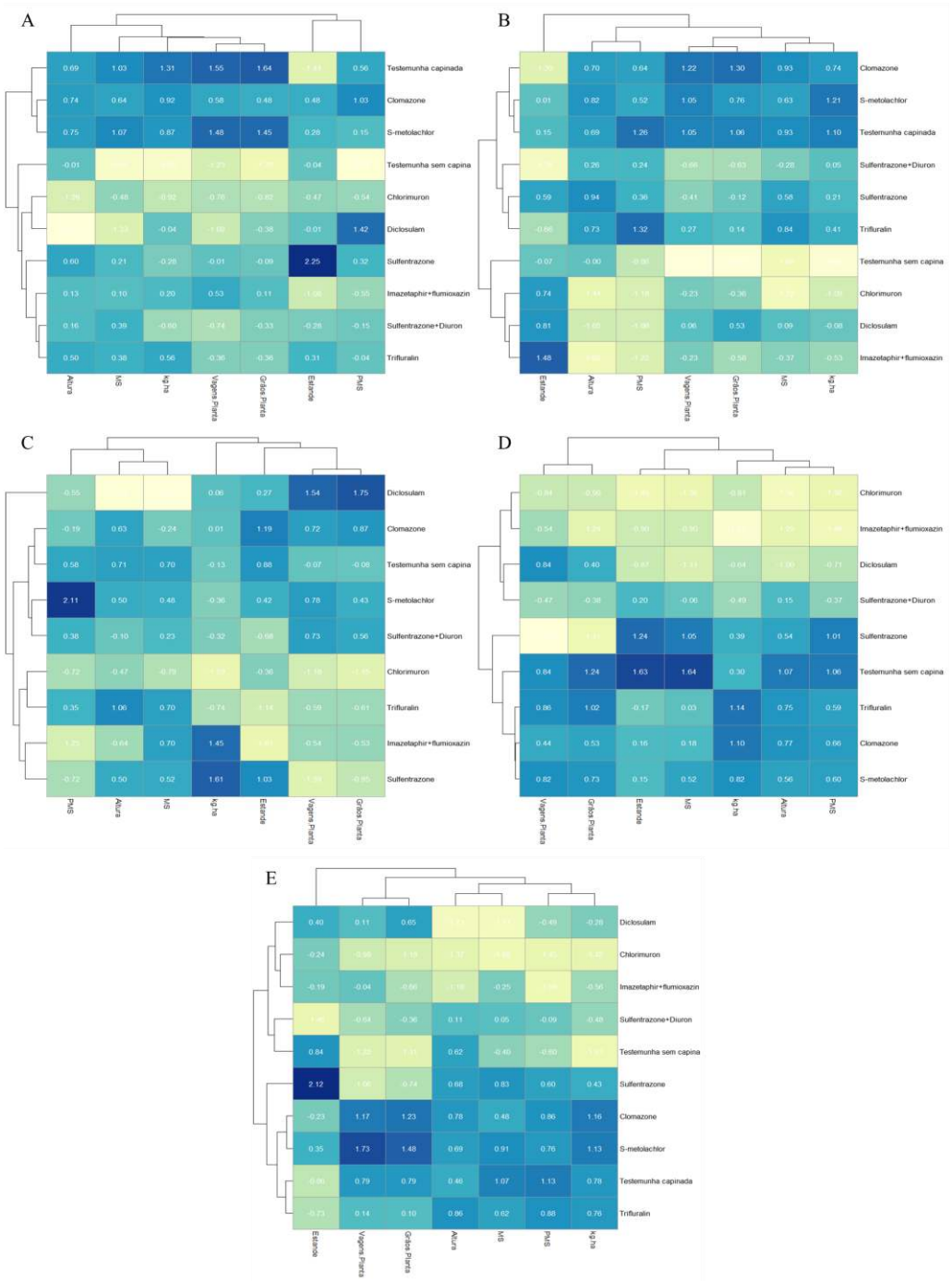


Figure 3. Exploratory similarity heatmap based on the Euclidean distance between the response profiles of 8 pre-emergence herbicides and the controls, in relation to productive and biometric characteristics. A – Efficacy trial, Site 1 (medium texture); B – Efficacy trial, Site 2 (sandy texture); C – Selectivity trial, Site 1; D – Selectivity trial, Site 2; and E – Sites 1 and 2 combined, with information from the efficacy and selectivity trials. The groupings are descriptive and do not constitute significance tests.

Source: Research data.

CC BY

REMUNOM
ISSN 2178-6925

Received: 25/08/2026 - **Accepted:** 03/09/2026
Vol: 13.19
DOI: 10.66104/mxj9qk49
Pages: 1-35

At Site 1 (medium texture), in both the efficacy trial (A) and the selectivity trial (C), the groupings showed less proximity between the herbicides and greater dispersion between treatments.

This pattern is compatible with the behaviour described for soils with higher cation exchange capacity and organic matter content, in which the retention of herbicide molecules tends to be more differentiated (FREITAS; SANTOS, 2019; JAREMTCHUK et al., 2009). At Site 2 (sandy texture), the treatments showed closer groupings, especially in the selectivity trial (D), which suggests less variability in the response between herbicides in that environment. As these are exploratory analyses, such patterns describe similarity between response profiles and do not identify, in isolation, the attribute responsible for the behaviour observed.

The combined representation of the data from the two sites (E) revealed two main clusters: one group containing the treatments associated with higher yield losses and/or higher injury (chlorimuron, imazethapyr + flumioxazin, diclosulam and sulfentrazone + diuron), and another with the herbicides that showed better agronomic performance (trifluralin, S-metolachlor, clomazone and sulfentrazone). This pattern is consistent with an influence of the soil-herbicide interaction on the agronomic response, as described by Takano et al. (2015), although the grouping itself does not test this hypothesis.

In dendrogram A (efficacy trials at Sites 1 and 2), two main groups were formed, one predominantly composed of treatments from Site 1 (medium texture) and the other of treatments from Site 2 (sandy texture). In dendrogram B (selectivity trials at Sites 1 and 2), two large groups were also formed, with the same tendency of separation by site. Since the treatments were grouped predominantly by site, these dendrograms indicate a global environment effect and do not allow the identification of the specific soil attribute responsible for the separation (Figure 4).

CC BY

REMUNOM
ISSN 2178-6925

Received: 25/08/2026 - **Accepted:** 03/09/2026
Vol: 13.19
DOI: 10.66104/mxj9qk49
Pages: 1-35

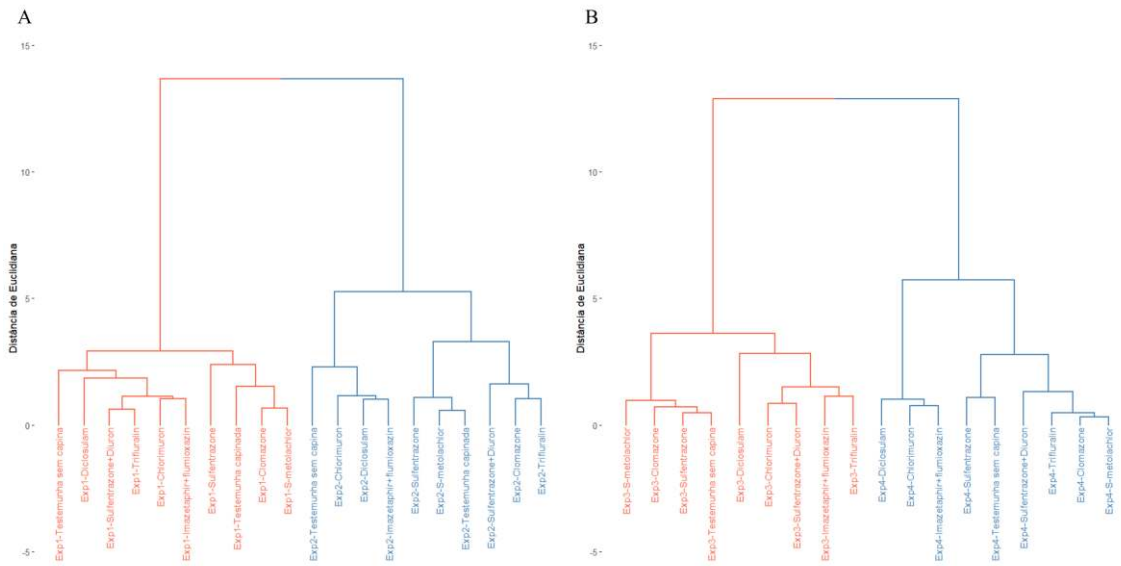


Figure 4. Exploratory cluster analysis based on Euclidean distance among eight pre-emergence herbicides plus the controls. A) Exp1 – Efficacy trial, Site 1 (medium texture) and Exp2 – Efficacy trial, Site 2 (sandy texture); B) Exp3 – Selectivity trial, Site 1 (medium texture) and Exp4 – Selectivity trial, Site 2 (sandy texture). The clusters describe proximity between response profiles and do not correspond to statistical comparisons between treatments.
Source: Research data.

The regression models fitted to the treatment means describe the temporal trend of the two responses (Tables 9 and 10). For control, the quadratic model was selected for all treatments at both sites, with coefficients of determination between 0.9381 and 0.9991; the negative sign of the linear term reflects the progressive decline in control between 14 and 35 DAA, which was steepest for chlorimuron and least pronounced for S-metolachlor. For injury, the fits describe two distinct temporal patterns: a transient one, in which symptoms peak at 7 DAE and return to zero (trifluralin, S-metolachlor, sulfentrazone, sulfentrazone + diuron and clomazone), and a persistent one, in which symptoms increase up to 21 DAE before declining (diclosulam, imazethapyr + flumioxazin and chlorimuron). As only four evaluation dates are available, these fits are descriptive and are not used to compare treatments.

CC BY

REMUNOM
ISSN 2178-6925

Received: 25/08/2026 - **Accepted:** 03/09/2026
Vol: 13.19
DOI: 10.66104/mxj9qk49
Pages: 1-35

Table 9. Regression models fitted to the mean control of *Eleusine indica* as a function of the evaluation date (x, in days after application), in the efficacy trials at two sites. Correntina, BA, 2018/2019.

Treatment	Model	Fitted equation	R^2	R^2adj
Site 1 – Faz. Brasholanda (medium texture)				
Trifluralin	quadratic	$y = 105.2900 - 1.1129x + 0.011224x^2$	0.9381	0.8143
S-metolachlor	quadratic	$y = 87.7700 + 0.6829x - 0.016327x^2$	0.9970	0.9909
Diclosulam	quadratic	$y = 47.1700 + 2.4471x - 0.054082x^2$	0.9730	0.9191
Imazethapyr + flumioxazin	quadratic	$y = 97.3950 - 1.2350x + 0.012755x^2$	0.9919	0.9756
Sulfentrazone	quadratic	$y = 74.6200 + 0.1543x - 0.016327x^2$	0.9988	0.9963
Sulfentrazone + diuron	quadratic	$y = 91.5450 - 0.9493x + 0.006633x^2$	0.9950	0.9850
Clomazone	quadratic	$y = 87.0950 + 0.7507x - 0.026020x^2$	0.9976	0.9927
Chlorimuron-ethyl	quadratic	$y = 94.7200 - 2.0529x + 0.025510x^2$	0.9681	0.9043
Site 2 – Faz. Boi Branco (sandy texture)				
Trifluralin	quadratic	$y = 96.5400 - 0.3843x - 0.007143x^2$	0.9716	0.9149
S-metolachlor	quadratic	$y = 93.4600 + 0.2129x - 0.009184x^2$	0.9661	0.8983
Diclosulam	quadratic	$y = 67.5250 + 1.4536x - 0.038265x^2$	0.9534	0.8603
Imazethapyr + flumioxazin	quadratic	$y = 99.8650 - 1.0450x + 0.013776x^2$	0.9848	0.9545
Sulfentrazone	quadratic	$y = 88.6550 - 0.2936x - 0.004592x^2$	0.9928	0.9783
Sulfentrazone + diuron	quadratic	$y = 80.9050 + 0.8279x - 0.030102x^2$	0.9846	0.9538
Clomazone	quadratic	$y = 99.3600 - 0.3300x - 0.005102x^2$	0.9991	0.9974
Chlorimuron-ethyl	quadratic	$y = 71.4450 + 0.5579x - 0.020918x^2$	0.9990	0.9969

Models fitted to the treatment means presented in Table 5. The model was selected by the R^2 criterion, as described in the methodology; R^2adj is the adjusted coefficient of determination. With four evaluation dates, the quadratic model retains one residual degree of freedom, so the fits are exploratory and descriptive.

Table 10. Regression models fitted to the mean visual injury to soybean as a function of the evaluation date (x, in days after emergence), in the selectivity trials at two sites. Correntina, BA, 2018/2019.

Treatment	Model	Fitted equation	R^2	R^2adj
Site 1 – Faz. Brasholanda (medium texture)				
Trifluralin	quadratic	$y = 7.4250 - 0.7307x + 0.016837x^2$	0.9333	0.8000
S-metolachlor	quadratic	$y = 6.7500 - 0.6643x + 0.015306x^2$	0.9333	0.8000
Diclosulam	quadratic	$y = -2.5250 + 2.6064x - 0.068878x^2$	0.9913	0.9740
Imazethapyr + flumioxazin	quadratic	$y = 3.6750 + 1.3764x - 0.039286x^2$	0.9903	0.9710
Sulfentrazone	quadratic	$y = 7.8750 - 0.7750x + 0.017857x^2$	0.9333	0.8000
Sulfentrazone + diuron	quadratic	$y = 12.5250 - 0.8436x + 0.013776x^2$	0.9511	0.8532
Clomazone	quadratic	$y = 13.5000 - 1.0571x + 0.020408x^2$	0.9939	0.9818

CC BY

REMUNOM
ISSN 2178-6925

Received: 25/08/2026 - **Accepted:** 03/09/2026
Vol: 13.19
DOI: 10.66104/mxj9qk49
Pages: 1-35

Treatment	Model	Fitted equation	R^2	R^2adj
Chlorimuron-ethyl	quadratic	$y = 2.0000 + 1.7500x - 0.045918x^2$	0.8347	0.5041
Site 2 – Faz. Boi Branco (sandy texture)				
Trifluralin	quadratic	$y = 17.6875 - 0.2625x - 0.014031x^2$	0.9414	0.8242
S-metolachlor	quadratic	$y = 15.5625 - 0.5982x + 0.001276x^2$	0.9907	0.9722
Diclosulam	quadratic	$y = -3.9375 + 4.1946x - 0.085459x^2$	0.8399	0.5198
Imazethapyr + flumioxazin	quadratic	$y = -2.1875 + 4.1089x - 0.075255x^2$	0.9406	0.8217
Sulfentrazone	quadratic	$y = 19.8125 - 0.6125x - 0.003827x^2$	0.9836	0.9508
Sulfentrazone + diuron	quadratic	$y = 16.0625 + 1.0875x - 0.059949x^2$	0.9836	0.9508
Clomazone	quadratic	$y = 23.1875 - 0.9518x + 0.003827x^2$	0.9746	0.9237
Chlorimuron-ethyl	quadratic	$y = -8.1250 + 4.8929x - 0.102041x^2$	0.9718	0.9154

Models fitted to the treatment means presented in Table 6. The model was selected by the R^2 criterion, as described in the methodology; R^2adj is the adjusted coefficient of determination. With four evaluation dates, the quadratic model retains one residual degree of freedom, so the fits are exploratory and descriptive.

The joint positioning of the treatments in the efficacy × selectivity matrix (Figure 5) summarises the contrast between the two environments. At Site 1, all eight herbicides fall in the upper half of the matrix, that is, none reduced grain yield by more than 5% relative to the weed-free control without herbicide; the treatments are distinguished only along the efficacy axis, with S-metolachlor, clomazone and trifluralin above the 80% control threshold at 35 DAA. At Site 2, the same eight herbicides are distributed between the two halves: S-metolachlor and clomazone remain in the quadrant of high efficacy and high selectivity; trifluralin and sulfentrazone maintained yields similar to or higher than that of the control without herbicide, but did not reach the 80% control threshold; diclosulam, sulfentrazone + diuron and chlorimuron combined control below 80% with yield reductions of 6.8%, 5.8% and 8.1%, respectively, in the absence of weed competition; and imazethapyr + flumioxazin was the only treatment to reach the control threshold while showing the largest yield reduction of the study in the weed-free trial (15.3%). Since the vertical axis derives from the trials kept free of weeds, the reductions observed in the lower half of the matrix express the response of the crop to the herbicide and not the interference of E. indica, whereas the horizontal axis isolates the residual efficacy. The displacement of four treatments into the lower half of the matrix at Site 2, without an equivalent at Site 1, is therefore the clearest expression of the

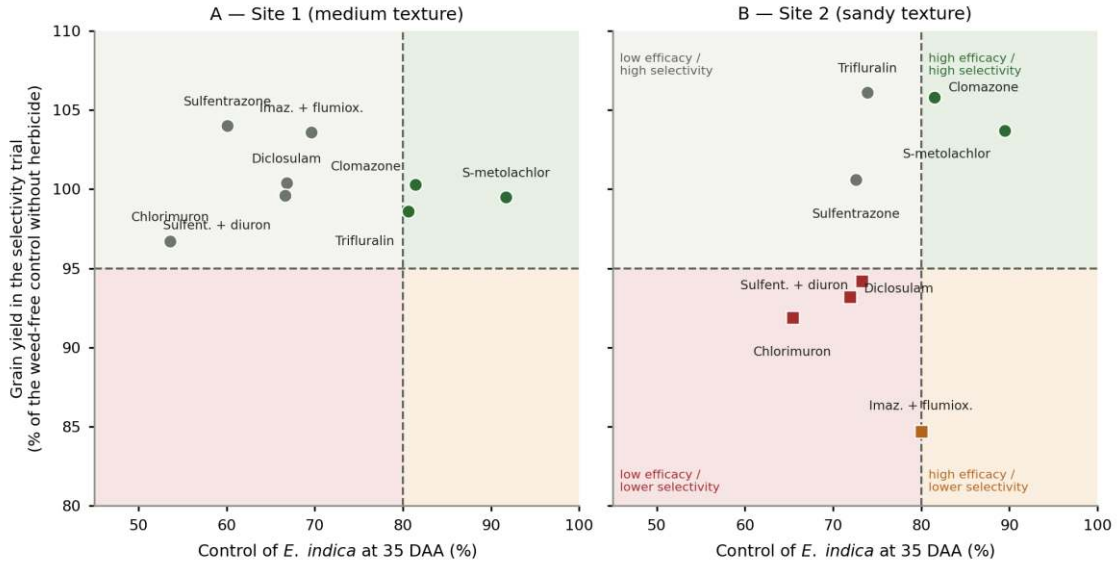
CC BY

REMUNOM
ISSN 2178-6925

Received: 25/08/2026 - **Accepted:** 03/09/2026
Vol: 13.19
DOI: 10.66104/mxj9qk49
Pages: 1-35

interaction between the treatments and the two edaphic environments.

Figure 5. Efficacy × selectivity matrix of the residual herbicides at the two sites. A – Site 1 (medium texture); B – Site 2 (sandy texture). Horizontal axis: control of *Eleusine indica* at 35 days after application, in the efficacy trials, with a threshold of 80%. Vertical axis: grain yield in the selectivity trials, expressed as a percentage of the weed-free control without herbicide, with a threshold of 95% (equivalent to a yield reduction of up to 5%). Circles indicate treatments above the selectivity threshold and squares those below it. The matrix is a descriptive synthesis of data from two distinct trials per site and does not constitute a joint statistical analysis.



Source: Research data.

These findings reinforce that the agronomic performance of pre-emergence herbicides cannot be evaluated in isolation by their initial efficacy, but must consider their interaction with the edaphic environment. Soil texture, by influencing the adsorption, leaching and availability of the active ingredient, may alter both the residual period and the selectivity of the herbicide (AMIM et al., 2014; TAKANO et al., 2015); in the present study, however, texture varied together with organic matter, pH, cation exchange capacity and base saturation, so that the individual contribution of each attribute cannot be separated. Therefore, dose adjustment and product selection should consider not only the target crop and the infestation, but also the physical and chemical environment of the soil, as previously discussed by Karpinski et al. (2014) and consistent with the results obtained here.

CC BY

REMUNOM
ISSN 2178-6925

Received: 25/08/2026 - **Accepted:** 03/09/2026
Vol: 13.19
DOI: 10.66104/mxj9qk49
Pages: 1-35

Some limitations of this study should be highlighted. First, the trials were conducted at only two sites, so that site, soil attributes and post-application rainfall are confounded; the contribution of clay content cannot be separated from that of organic matter, pH, effective cation exchange capacity or base saturation. Second, the two sites are specific contrasting edaphic environments and were treated as a fixed factor, so the results should not be extrapolated as representative of all soils or production environments. Third, the resistance status of the E. indica populations present in the experimental areas was not determined and the initial infestation was not quantified as plant density, which limits comparison with studies that report resistant biotypes or defined infestation levels. Fourth, the multivariate analyses used here are exploratory and describe similarity between response profiles without testing causal hypotheses; the regression models were fitted to only four evaluation dates and are also used in a descriptive manner. Finally, the data refer to the 2018/2019 season; although the physicochemical behaviour of the molecules in the soil is not expected to change, the registration framework of the products and the resistance status of the species may have changed since then, which should be taken into account in the practical application of these results.

4. Conclusion

In the four field trials conducted in two contrasting edaphic environments, the residual herbicides differed both in their efficacy against Eleusine indica and in the agronomic response of soybean. S-metolachlor, clomazone and trifluralin showed the most consistent control profiles under the conditions evaluated, whereas the treatments with lower residual efficacy, particularly chlorimuron, were associated with greater weed interference in the efficacy trials.

In the selectivity trials, conducted without weed competition, the crop responses differed between the two environments: at Site 1, no treatment reduced grain yield relative to the control without herbicide, whereas at Site 2 diclosulam, imazethapyr + flumioxazin and chlorimuron caused the highest visual injury and were associated with the lowest yields. Visual injury, biometric variables and grain yield are distinct responses and were interpreted separately: transient injury

CC BY

REMUNOM
ISSN 2178-6925

Received: 25/08/2026 - **Accepted:** 03/09/2026
Vol: 13.19
DOI: 10.66104/mxj9qk49
Pages: 1-35

symptoms were recorded for treatments that did not reduce yield, and reductions in plant height and shoot dry mass occurred without a corresponding yield loss at Site 1.

Because the two sites differed simultaneously in clay content, organic matter, pH, effective cation exchange capacity and base saturation, and because the two sets of trials also differed in accumulated rainfall after application, the present design does not allow the individual contribution of each soil attribute to be isolated. The results should therefore be interpreted as evidence of an interaction between the treatments and contrasting edaphic environments, reinforcing the need to adjust the choice and the dose of residual herbicides to soil characteristics and to the specific technical recommendations for each product.

Referências

ASOCIACIÓN LATINOAMERICANA DE MALEZAS. Recomendaciones sobre unificación de los sistemas de evaluación en ensayos de control de malezas. **ALAM**, v. 1, n. 1, p. 35–38, 1974.

AMIM, R. T. et al. Weed control by indaziflam in soils with different physicochemical characteristics. **Planta Daninha**, v. 32, n. 4, p. 791–800, 2014. DOI: https://doi.org/10.1590/S0100-83582014000400014.

BECKIE, H. J.; ASHWORTH, M. B.; FLOWER, K. C. Herbicide resistance management: recent developments and trends. Plants, v. 8, p. 2–13, 2019.

BRAZ, G. B. P.; BIFFE, D. F.; CONSTANTIN, J.; OLIVEIRA JR., R. S.; PROCÓPIO, S. O.; REIS, G.; BARION, J. H. R. Goosegrass management challenges in Brazil: the ongoing battle against herbicide resistance. Advances in Weed Science, v. 43, e020250008, 2025. DOI: https://doi.org/10.51694/AdvWeedSci/2025;43:00033.

CHAUHAN, B. S.; JOHNSON, D. E. Germination ecology of goosegrass (Eleusine indica): an important grass weed of rainfed rice. Weed Science, v. 56, p. 699–706, 2008.

CC BY

REMUNOM
ISSN 2178-6925

Received: 25/08/2026 - **Accepted:** 03/09/2026
Vol: 13.19
DOI: 10.66104/mxj9qk49
Pages: 1-35

CHAUHAN, B. S. et al. Emerging challenges and opportunities for education and research in weed science. **Frontiers in Plant Science**, v. 8, art. 1537, 2017.

CHEN, J. C. et al. Characterization of glyphosate-resistant goosegrass (*Eleusine indica*) populations in China. **Journal of Integrative Agriculture**, v. 14, p. 919–925, 2015.

CHRISTOFFOLETI, P. J. et al. **Soil-applied herbicide behavior in sugarcane**. Piracicaba: CP2, 2008.

DUARY, B. Recent advances in herbicide resistance in weeds and its management. **Indian Journal of Weed Science**, v. 40, n. 3/4, supl., p. 124–135, 2008.

EUROPEAN WEED RESEARCH COUNCIL. Report of the 3rd and 4th meetings of EWRC: Committee of Methods in Weed Research. **Weed Research**, v. 4, n. 1, p. 88, 1964.

FREITAS, A. P.; SANTOS, A. S. Different soil textures under residual effect of the formulated mixture diuron + hexazinone + sulfometuron-methyl. **Nucleus**, v. 16, n. 2, p. 453–462, 2019. DOI: https://doi.org/10.3738/1982.2278.3674.

FREITAS, M. A. M. et al. Sorption of sulfentrazone in different soil types determined by bioassays. **Planta Daninha**, v. 32, n. 2, p. 385–392, 2014.

GAGE, K. L.; KRAUSZ, R. F.; WALTERS, S. A. Emerging challenges for weed management in herbicide-resistant crops. **Agriculture**, v. 9, p. 2–11, 2019.

GARWOOD, N. C. Tropical soil seed banks: a review. In: LECK, M. A.; PARKER, V. T.; SIMPSON, R. L. (ed.). **Ecology of soil seed banks**. San Diego: Academic Press, 1989.

CC BY

REMUNOM
ISSN 2178-6925

Received: 25/08/2026 - **Accepted:** 03/09/2026
Vol: 13.19
DOI: 10.66104/mxj9qk49
Pages: 1-35

HANSON, B. D. et al. Herbicide-resistant weeds challenge some signature cropping systems. **California Agriculture**, v. 68, p. 142–152, 2014.

HRAC GLOBAL – HERBICIDE RESISTANCE ACTION COMMITTEE. *HRAC mode of action classification 2020*. [S. l.]: HRAC Global, 2020. Available at: https://hracglobal.com/files/HRAC_Revised_MOA_Classification_Herbicides_Poster.pdf. Accessed on: 4 Sept. 2026.

HEAP, I. The international survey of herbicide resistant weeds. Weedscience.org, 2026. Disponível em: https://www.weedscience.org/. Acesso em: 4 set. 2026.

JALALUDIN, A.; YU, Q.; POWLES, S. B. Multiple resistance across glufosinate, glyphosate, paraquat and ACCase-inhibiting herbicides in an *Eleusine indica* population. **Weed Research**, v. 55, p. 82–89, 2015.

JAREMTCHUK, C. C. et al. Residual effect of flumioxazin on weed emergence in soils with different textures. **Planta Daninha**, v. 27, n. 1, p. 191–196, 2009. DOI: https://doi.org/10.1590/S0100-83582009000100024.

KARPINSKI, R. A. K. et al. Influence of soil texture on the selectivity of the herbicide fomesafen applied in pre-emergence to cotton. **Revista Brasileira de Herbicidas**, v. 13, n. 2, p. 125, 2014. DOI: https://doi.org/10.7824/rbh.v13i2.283.

KAUNDUN, S. S. et al. Importance of the P106S target-site mutation in conferring resistance to glyphosate in goosegrass (*Eleusine indica*) from the Philippines. **Weed Science**, v. 56, n. 5, p. 637–646, 2008.

KISSMANN, K. G. **Weed and harmful plants**. São Paulo: BASF, 2007.

CC BY

REMUNOM
ISSN 2178-6925

Received: 25/08/2026 - **Accepted:** 03/09/2026
Vol: 13.19
DOI: 10.66104/mxj9qk49
Pages: 1-35

KOLDE, R. **pheatmap: Pretty Heatmaps**. R package version 1.0.12, 2019. Disponível em: https://CRAN.R-project.org/package=pheatmap. Acesso em: 2 set. 2026.

LAGATOR, M. et al. Herbicide mixtures at high doses slow the evolution of resistance in experimentally evolving populations of *Chlamydomonas reinhardtii*. **New Phytologist**, v. 198, p. 938–945, 2013.

LEE, L. J.; NGIM, J. First report of glyphosate-resistant goosegrass (*Eleusine indica*) in Malaysia. **Pest Management Science**, v. 56, n. 1, p. 336–339, 2000.

LÚCIO, F. R. et al. Dispersal and frequency of glyphosate-resistant and tolerant weeds in soybean-producing microregions in Brazil. **Weed Technology**, v. 33, p. 217–231, 2019.

MA, X. et al. Emergence timing affects growth and reproduction of goosegrass (*Eleusine indica*). **Weed Technology**, 2019. DOI: https://doi.org/10.1017/wet.2019.61.

MCCULLOUGH, P. E. et al. First report of ACCase-resistant goosegrass (*Eleusine indica*) in the United States. **Weed Science**, v. 64, p. 399–408, 2016.

MONQUERO, P. A. et al. Herbicides selectivity on seedlings of native species *Acacia polyphylla*, *Enterolobium contortisiliquum* (Fabaceae), *Ceiba speciosa* and *Luehea divaricata* (Malvaceae). **Planta Daninha**, v. 29, n. 1, p. 159–168, 2011. DOI: https://doi.org/10.1590/S0100-83582011000100018.

MUELLER, T. C. et al. Glyphosate-resistant goosegrass (*Eleusine indica*) confirmed in Tennessee. **Weed Science**, v. 59, n. 4, p. 562–566, 2011.

CC BY

REMUNOM
ISSN 2178-6925

Received: 25/08/2026 - **Accepted:** 03/09/2026
Vol: 13.19
DOI: 10.66104/mxj9qk49
Pages: 1-35

NEGRISOLI, E. et al. Selectivity of pre-emergence herbicides applied in sugarcane treated with nematicides. **Planta Daninha**, v. 22, n. 4, p. 567–575, 2004.

NORDMEYER, H. Herbicide application in precision farming based on soil organic matter. **American Journal of Experimental Agriculture**, v. 8, p. 144–151, 2015.

NUNES, A. L. et al. A multi-year study reveals the importance of residual herbicides on weed control in glyphosate-resistant soybean. **Planta Daninha**, v. 36, e0181806, 2018.

OLIVEIRA JR., R. S.; INOUE, M. H. Herbicide selectivity for crops and weeds. In: OLIVEIRA JR., R. S.; CONSTANTIN, J.; INOUE, M. H. (ed.). **Biology and management of weeds**. Curitiba: Omnipax, 2011. p. 243–262.

OLIVEIRA NETO, A. M. et al. Burndown systems in winter wheat areas and residual herbicide activity in soybean. **Revista Brasileira de Herbicidas**, v. 12, n. 1, p. 14–22, 2013.

PEREIRA, F. D. A. R. et al. Selectivity of sulfentrazone in soybean cultivars and residual effects on succeeding crops in Cerrado soils. **Revista Brasileira de Herbicidas**, v. 1, n. 3, p. 219, 2000. DOI: https://doi.org/10.7824/rbh.v1i3.338.

PROCÓPIO, S. O. et al. Effect of initial irrigation on the leaching depth of S-metolachlor in different soil types. **Planta Daninha**, v. 19, n. 3, p. 409–417, 2001. DOI: https://doi.org/10.1590/S0100-83582001000300014.

R CORE TEAM. **R: A language and environment for statistical computing**. Vienna: R Foundation for Statistical Computing, 2025. Disponível em: https://www.R-project.org/. Acesso em: 2 set. 2026.

CC BY

REMUNOM
ISSN 2178-6925

Received: 25/08/2026 - **Accepted:** 03/09/2026
Vol: 13.19
DOI: 10.66104/mxj9qk49
Pages: 1-35

ROMAN, E. S. et al. Ryegrass (*Lolium multiflorum*) resistance to glyphosate. **Planta Daninha**, v. 22, n. 2, p. 301–306, 2004.

SANTOS, H. G. et al. **Sistema brasileiro de classificação de solos**. 3. ed. rev. ampl. Brasília, DF: Embrapa, 2013.

SILVA, W. L. Herbicidas residuais no controle de *Eleusine indica* e na seletividade da cultura da soja. 2020. Dissertação (Mestrado em Ciências Agrárias – Agronomia) – Instituto Federal de Educação, Ciência e Tecnologia Goiano, Urutaí, 2020. Disponível em: https://repositorio.ifgoiano.edu.br/handle/prefix/1202. Acesso em: 4 set. 2026.

SOMERVILLE, G. J. et al. Why was resistance to shorter-acting pre-emergence herbicides slower to evolve? **Pest Management Science**, v. 73, p. 844–851, 2017.

TAKANO, H. K. et al. Dry season and soil texture affect chemical control of *Senna obtusifolia* in sugarcane. **Revista Brasileira de Herbicidas**, v. 14, n. 3, p. 181, 2015. DOI: https://doi.org/10.7824/rbh.v14i3.403.

TAKANO, H. K. et al. Growth, development and seed production of goosegrass. **Planta Daninha**, v. 34, p. 249–258, 2016.

TAKANO, H. K. et al. Goosegrass resistant to glyphosate in Brazil. **Planta Daninha**, v. 35, e0171678, 2017.

ULGUIM, A. R. et al. Management of goosegrass in glyphosate-resistant soybean fields. **Pesquisa Agropecuária Brasileira**, v. 48, n. 1, p. 17–24, 2013.

CC BY

REMUNOM
ISSN 2178-6925

Received: 25/08/2026 - **Accepted:** 03/09/2026
Vol: 13.19
DOI: 10.66104/mxj9qk49
Pages: 1-35

VARANASI, A.; PRASAD, P. V. V.; JUGULAM, M. Impact of climate change factors on weeds and herbicide efficacy. **Advances in Agronomy**, v. 135, p. 107–146, 2016.

VENCILL, W. K. et al. Herbicide resistance: toward an understanding of resistance development and the impact of herbicide-resistant crops. **Weed Science**, v. 60, n. esp., p. 2–30, 2012.

VIDAL, R. A. et al. Resistance of *Eleusine indica* to ACCase inhibitors. **Planta Daninha**, v. 24, p. 163–171, 2006.

WESTWOOD, J. H. et al. Weed management in 2050: perspectives on the future of weed science. **Weed Science**, v. 66, p. 275–285, 2018.

WICKHAM, H. **ggplot2: Elegant graphics for data analysis**. New York: Springer-Verlag, 2016. Disponível em: https://ggplot2.tidyverse.org/. Acesso em: 2 set. 2026.

CC BY