Australian Journal of Crop Science AJCS
AJCS 18(1):21-28 (2024) ISSN:1835-2707
doi: 10.21475/ajcs.24.18.01.p4018

Received: 03/08/2023
Revised: 22/09/2023
Accepted:10/10/2023

Pre-emergence herbicides effects in no-till soybean system with Panicum maximum 'BRS Tamani'

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Abstract

The use of pre-emergence herbicides is an important strategy in resistant-weeds management, but its performance can be affected in no-till systems. This study aimed to analyse weed control from pre-emergence herbicides in no-till soybean system with *Panicum maximum* cv. BRS Tamani. The experiment was conducted in randomized block design with eight treatments and five repetitions. The treatments consisted in no-treatment, S-metolachlor + imazethapyr (1,200.00 g a.i. ha^{-1} + 100.00 g a.e. ha^{-1}, respectively), S-metolachlor + fomesafen (1,035.66 g a.i. ha^{-1} + 227.70 g a.e. ha^{-1}, respectively), S-metolachlor + diclosulam (1.200.00 g a.i. ha^{-1} + 29.40 g a.i. ha^{-1}), imazethapyr + diclosulam (100.00 g a.e. ha^{-1} + 29.40 g a.i. ha^{-1}), imazethapyr + flumioxazin (100.00 g a.e. ha^{-1} + 50.00 g a.i. ha^{-1}), pyroxasulfone + flumioxazin (90.00 g a.i. ha^{-1} + 60.00 g a.i. ha^{-1}) and pendimethalin (1,137.50 g a.i. ha^{-1}). We evaluated weed phytosociological rates, weed control, and soybean growth. We identified 23 weed species distributed in 22 genera and 15 botanical families, majority of eudicotyledonous botanical class (78.2%), annual life cycle (56.5%), and sexual reproduction (100%). The integrated weed management, between herbicides and straw, was effective in herbicide-resistant weed control, except *Euphorbia heterophylla*. The treatments recommended included S-metolachlor combinations with fomesafen, imazethapyr, diclosulam, and also, pyroxasulfone + flumioxazin. The *Panicum maximum* cv. BRS Tamani straw was estimated in 11 t ha^{-1} and influenced negatively herbicides lipophilics and with slower movement, such as pendmethalin.

Introduction

The soybean crop [*Glycine max* (L.) Merril] is one of the most produced oilseeds worldwide. Currently, Brazil is the world's largest producer and exporter of soybean, with 154,566.3 thousand tons in 44,062.6 thousand hectares in the 2023 harvest (CONAB, 2023). In Brazil, the no-till system has occupied more than 90% of the soybean production area. This production system increases soil carbon and weed control compared to conventional management, however, it is extremely herbicides dependent (Patel et al., 2023).
The herbicides indiscriminate use can cause resistant weeds selection (Jones et al., 2022). Actually, there are 51 herbicide-resistant weeds reported in Brazil and last decade has been registered 10 species resistant to glyphosate (Gazola et al., 2021). The estimated annual cost with herbicide-resistant weeds in soybean crops may reach US$ 2.7 billion when considering production losses for weed competition (Adegas et al., 2017).
The pre-emergence herbicides are indicated to help in the management of resistant weeds in soybean crops (Silva et al., 2021a). These herbicides have residual activity in the soil and can inhibit weed emergence during the critical interference phase in the crop. It can improve glyphosate control, the main herbicide used in the post-emergence of soybean genetically engineered (Soltani et al., 2017).
The integrated weed management in a no-till farming system also contributes to weed control compared to conventional planting systems (Summers et al., 2021). *Panicum maximum* is a cover crop currently used in Brazilian integrated cultivation systems. It is a forage species that has easy establishment, low growth, abundant leaves and tillers, spittlebugs resistance, and drought tolerance. It can greatly contribute to straw increase, water infiltration, soil decompaction, and glyphosate resistant-weeds management (Jank et al., 2021).
However, straw can become a barrier to herbicide action in soil consequently increasing the herbicide volatilization or photodegradation, depending on the herbicides' physicochemical properties and also straw origin, straw amount, rainfall event after spraying, and subsequent rainfall events (Khalil et al., 2019). The pre-emergent herbicides performance is complex and can be altered for soil properties, terrain, production system, and weed history (Matte et al., 2019).
The residual herbicides use, such as diclosulam, flumioxazin, imazethapyr, pendimethalin, pyroxasulfone, and S-

metolachlor are currently used in Brazilian soybean systems. These herbicides are AHAS (diclosulam and imazethapyr), protoporphyrinogen oxidase – Protox (flumioxazin), and cell division (pendimethalin, pyroxasulfone, and S-metolachlor) inhibitors. The fomesafen has been used in broadleaves burned operations and recently increasing control post-emergent in pre-emergence combinations in soybean planting. Actually, there are few studies about its reaction in integrated soybean systems with *Panicum maximum* coverage (Ovejero et al., 2019, Carbonari et al., 2016).

Therefore, the aim was to analyse the performance of pre-emergence herbicides in no-till soybean under *Panicum maximum* 'BRS Tamani' coverage.

Results and Discussion

Floristic survey, similarity, and weed distribution

In weed surveys that were identified 22 genera and 16 botanical families. In general, these species were eudicotyledonous (78.2%) with an annual life cycle (56.5%) and sexual reproduction (100%) (Table 1). These results corroborate with Silva et al. (2018) and Furtado et al. (2022) in weed surveys in the Brazilian northeast, and Albuquerque et al. (2021) Brazil north region.

Some species identified in post-soybean seeding such as *Amaranthus hybridus*, *Eleusine indica,* and *Euphorbia heterophylla* are listed glyphosate-resistant weeds in Brazil (Heap, 2018; Adegas et al., 2022). Also, Cyperus sp.*, C. echinatus, E. hirta, R. braziliensis* were reported with glyphosate-tolerant weeds in Brazilian soybean systems (Albrecht et al., 2022; Bottcher et al., 2022). Possibly, it means a low weed control by glyphosate before soybean seeding. According to Pazuch et al. (2017), glyphosate-resistant weed occurrence in systems of the same botanical class can cause problems of competition and herbicide selectivity in post-emergence.

The *C. rotundus, D. tortuosum, E. indica, E. heterophylla, E. hirta, M. verticillata, R. brasiliensis, S. dulcis, S. verticillata, and T. subulata* occurred in both surveys, before soybean cultivation and post soybean seeding. Thus, this was estimated at 60.6% similarity, in accordance with Matte et al. (2022). Certainly, its weed survival in integrated no-till management may be associated with its aggressive mechanisms and competitive ability, especially high germination, emergence, and growth under low light conditions, and also herbicide resistance (Nichols et al., 2015).

The eudicotyledonous weeds were distributed throughout the soybean field (Fig. 3B), while the monocotyledonous showed an aggregate behaviour in a few points (Fig. 3A). According to Ferreira et al., (2013), the eudicotyledonous weeds predominance may be associated to management adaptation. Especially lower glyphosate control and few cultural effects of *P. maximum* straw on germination and emergence weeds.

D. tortuosum (117.51), *T. subulata (*39.30), and *E. heterophylla (*33.61) were the most relevant in before soybean seeding (Fig. 4A), while *S. verticillata* (58.67), *C. rotundus* (51.60) and *D. tortuosum* (33.72) at soybean post-seeding (Fig. 4B). These species were also identified by Silva et al. (2021) and Furtado et al. (2022) in soybean systems on Maranhão (Brazil); Albuquerque et al. (2021) in Roraima (Brazil); Machado et al. (2015) in Paraná (Brazil); and Cruz et al. (2019) in Minas Gerais (Brazil).

Weed control for botanical class and glyphosate-resistant weeds

The pre-emergence treatments were more effective than the no-treatment. Thus, the *P. maximum* straw control was effectively complemented for residual herbicides (Fig. 5). These results are similar to Patel et al. (2023) who observed persistence increasing in soil with the presence of straw on the soil surface.

For monocotyledonous control the most effective treatments were S-metolachlor + fomesafen (92%), S-metolachlor + imazetapyr (91%) and S-metolachlor + diclosulam (90%). These results corroborate with Coradin et al. (2019) and Whalen et al. (2019) who reported the S-metolachlor control on glyphosate-resistant weeds. Cornelius et al. (2017) explained that S-metolachlor is a molecule cell division inhibitor and a strong graminicide, with low vapour pressure, medium lipophilicity, medium solubility, and low leaching. Thus, its physicochemical characteristics associated with rainfall events after spraying (Fig. 1) may have benefited the carriage of S-metolachlor at the soil and seed weed bank.

In eudicotyledonous species, pyroxasulfone + flumioxazin (76%) and imazetapyr + diclosulam (74%) stood out (Fig. 5). According to Khalil et al. (2019), pyroxasulfone is an herbicide used mainly for grass control and acts on small-seeded broadleaves. They stated that even in systems with large straw amounts, pyroxasulfone can cross the barrier and reach the soil. Possibly the rainfall events after spraying also contributed to pyroxasulfone and flumioxazin transport at the soil and weed seed bank.

The treatments imazetapyr + diclosulam and imazetapyr + flumioxazin obtained low performance in mono and eudicotyledonous control, respectively. In contrast to Silva et al. (2021), Muller et al. (2017) observed excellent performance from flumioxazin and diclosulam alone on glyphosate-resistant weeds, but in higher doses and conventional planting systems.

S-metolachlor + imazetapyr, S-metolachlor + fomesafen and S-metolachlor + diclosulam showed excellent control on *C. rotundus* (Fig. 6A), consonant with Zangoueinejad et al. (2020), who reported high efficiency of S-metolachlor on Cyperaceae control. Imazetapyr + diclosulam and imazetapyr + flumioxazin obtained a low performance, in contrast to Kumar et al. (2012) and Sharma et al. (2021) who reported good efficiency of imazethapyr in *Cyperus sp*.

Possibly, the prolonged use of imazethapyr on the farm may have resulted in its low control. *D. tortuosum* was satisfactorily controlled for imazethapyr + diclosulam (100%) and pyroxasulfone + flumioxazin (62%) (Fig. 6B). These results corroborate with Silva et al. (2021), Kupper et al. (2017) and Golubev (2021), studying AHAS and Protox inhibitors herbicides in glyphosate- tolerant weeds. Also, every treatment showed 100% control on *E. indica* (Fig. 6C), this implies it is susceptible to all mechanisms of action used. Emphasizing the pre-emergence control and herbicide rotation with efficient strategies in glyphosate-resistant weeds management, such as *E. indica* (López- Ovejero et al., 2013).

In contrast, *E. heterophylla* showed unsatisfactory control in all pre-emergent treatments (Fig. 7D), similar to Oliveira et al. (2013) and Palma- Bautista et al. (2020) testing imazethapyr, diclosulam and fomesafen, and Gazola et al. (2021) with diclosulam. But, Gazola et al. (2021) reported high control with flumioxazin (80%) and sulfentrazone (100%).

Table 1. List of weeds identified before soybean seeding and post soybean seeding, for family, genus, scientific nomenclature species, botanical class, phenological cycle, and reproduction. Brejo, Maranhão, Brazil.

Family	Genus	Species	Class	Cycle	Reproduction
Amaranthaceae	*Amaranthus*	*A. hybridus*	E	A	S
Asclepiadaceae	*Asclepias*	*A. curassavica*	E	P	As/S
Asteraceae	*Jaegeria*	*J. hirta*	E	A	S
Commelinaceae	*Commelina*	*C. benghalensis*	M	P	As/S
Convolvulaceae	*Ipomoea*	*I. grandifolia*	E	A	S
Cypereaceae	*Cyperus*	*C. rotundus*	M	P	As/S
Euphorbiaceae	*Euphorbia*	*E. hirta*	E	A	S
	Euphorbia	*E. heterophylla*	E	A	S
Fabaceae	*Crotalaria*	*C. incana*	E	A	S
	Desmondium	*D. tortuosum*	E	A	S
	Mimosa	*M. pudica*	E	P	S
Lecythidaceae	*Lecythis*	*L. lurida*	E	P	S
Malvaceae	*Herissantia*	*H. crispa*	E	P	S
	Malvastrum	*M. coromandelianumun*	E	A/P	S
Molluginaceae	*Mollugo*	*M. verticillata*	E	A	S
Nyctaginaceae	*Boerhavia*	*B. diffusa*	E	P	S
Poaceae	*Cenchrus*	*C. echinatus*	M	A	S
	Eleusine	*E. indica*	M	A	S
Rubiaceae	*Richardia*	*R. brasiliensis*	E	A	S
	Spermacoce	*S. verticillata*	E	P	S
Scrophulariaceae	*Scoparia*	*S. dulcis*	E	A	S
Turneraceae	*Turnera*	*T. subulata*	E	P	S

Note – E: Eudicotyledonous, M: Monocotyledonous, A: Annual, P: Perennial, As: Asexual, S: Sexual.

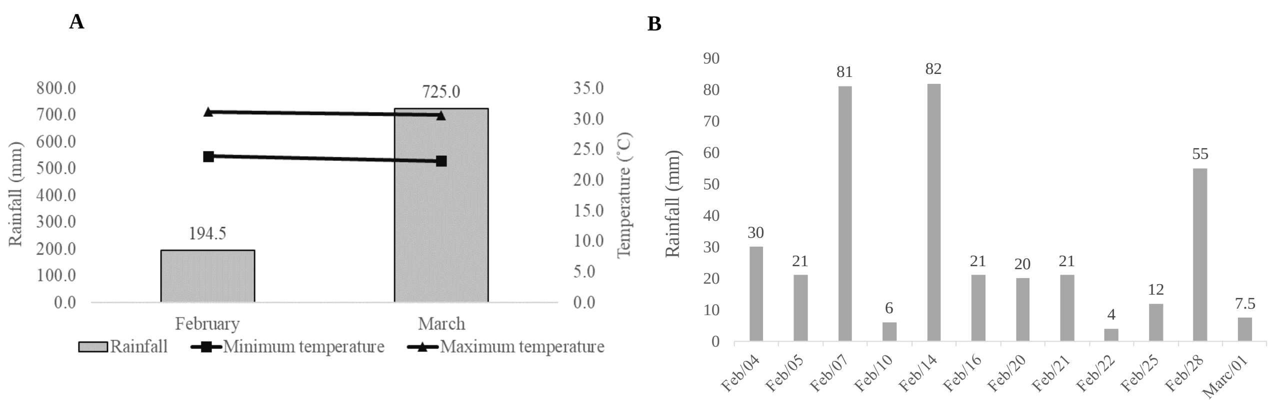

Figure 1. Rainfall events in evaluation phase. 1A: Rainfall database in Brejo, Maranhão, Brazil. 1B: Rainfall database in experimental field.

Table 2. Soybean evaluations at 25 DAS, under pre-emergence herbicides effects.

Treatment	Phytotoxicity grade	Phenology	NDVI
No-treatment	1.00	4.16 A	0.67 A
S-me + Ima	1.00	3.62 AB	0.36 C
S-me + Fom	1.00	3.64 AB	0.41 C
S-me + Dic	1.00	3.59 AB	0.41 C
Ima + Dic	1.00	3.21 B	0.39 C
Ima + Flu	1.00	3.97 AB	0.44 BC
Pir + Flu	1.00	4.33 A	0.48 BC
Pendimethalin	1.00	4.11 AB	0.57 AB
CV (%)	-	11.70	12.54

Note – Dic: Diclosulam, Flu: Flumioxazin, Fom: Fomesafen, Ima: Imazetaphyr, S-met: S-metolachlor.

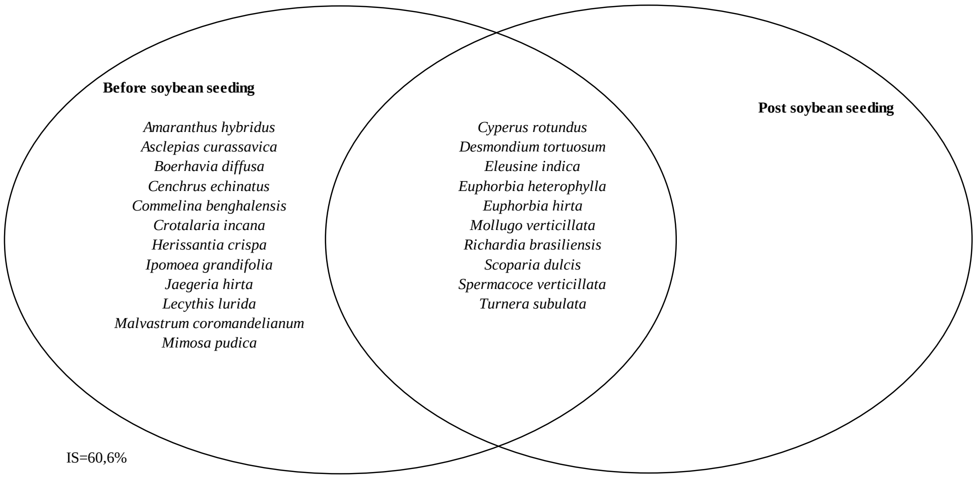

Figure 2. Species exclusive and shared in two weed survey phases: before soybean seeding and post soybean seeding. Weed Similarity for Sorensen methods (IS) was estimated in 60.6%.

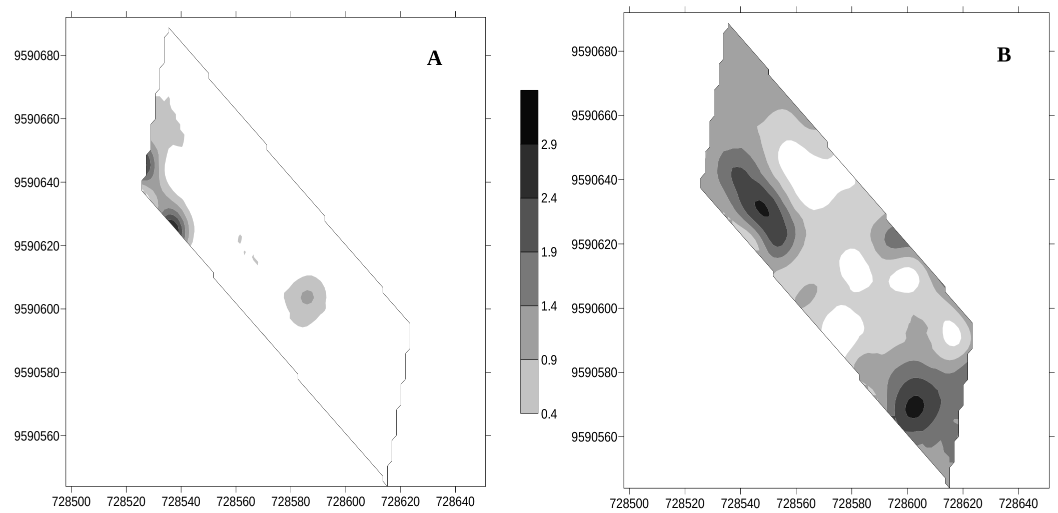

Figure 3. Spatial weed distribution on monocotyledonous (**A**) and eudicotyledonous (**B**) botanical class before soybean seeding. The database was expressed in weed density, plants for meter square (pl m^{-2}).

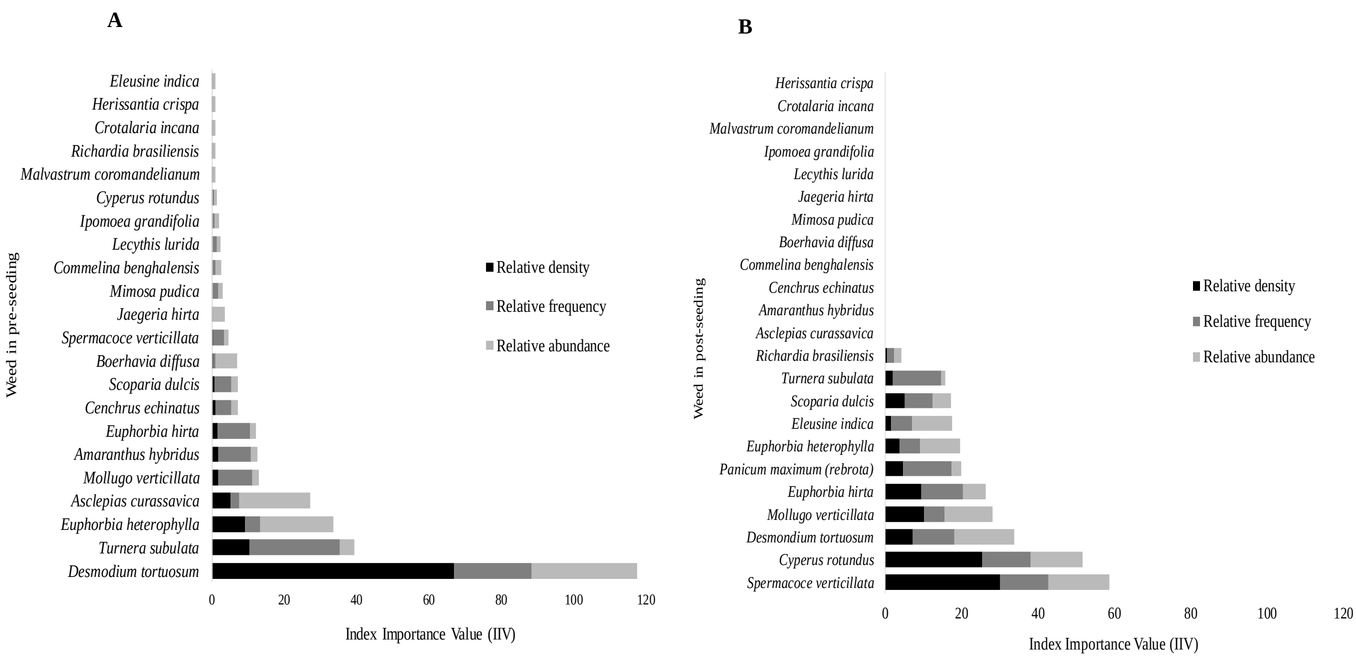

Figure 4. Weed importance value before soybean seeding (**4A**) and post soybean seeding (**4B**). Species with bar graph without consists in death plants in the post soybean seeding.

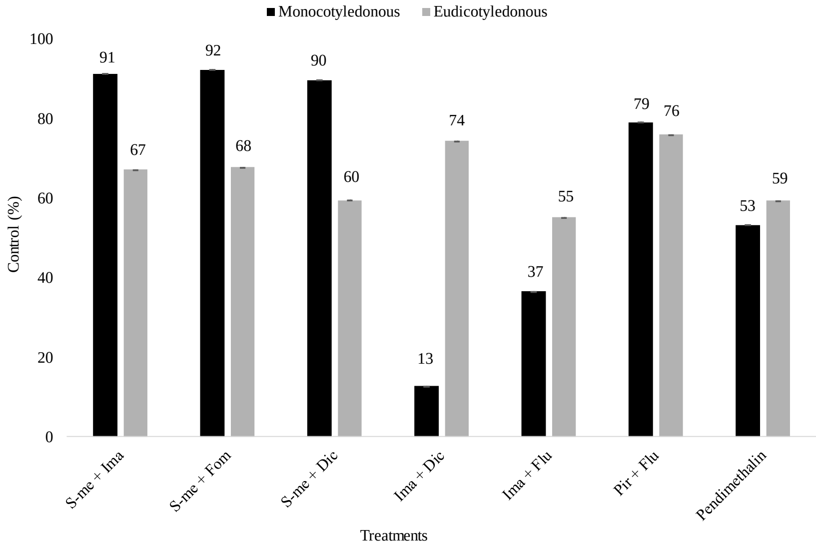

Figure 5. Monocotyledonous and eudicotyledonous weeds control in soybean post seeding, under pre-emergent herbicides effects.

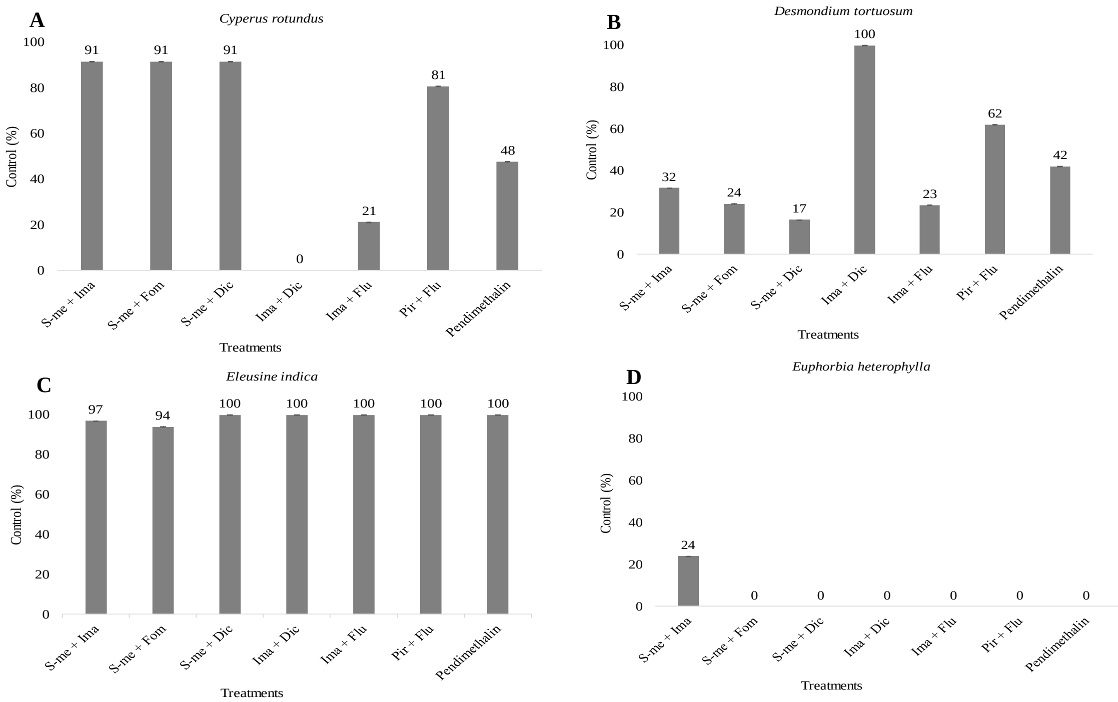

Figure 6. Glyphosate-tolerant and glyphosate-resistant weeds control in post soybean seeding, under pre-emergent herbicides effects. **6A:** *Cyperus rotundus*. **6B:** *Desmodium tortuosum*. **6C:** *Eleusine indica*. **6D:** *Euphorbia heterophylla.*

Palma-Bautista et al. (2020) and Vargas et al. (2013) described that *E. heterophylla* has been biotypes resistant to EPSPs, ALS, and Protox herbicides inhibitors, in accordance with our results, whose EPSPs inhibitor got no control before soybean seeding, even in 2,4-D combination. Likewise, flumioxazin and fomesafen (Protox inhibitors), imazethapyr, and diclosulam (AHAS inhibitors) presented low efficiency in pre-emergence.

Pre-emergent herbicide selectivity on soybean

The treatments were selective of the soybean, expressed for an average score of 1.0 (no phytotoxicity symptoms) in visual diagnostics (Table 2). The combination imazethapyr + diclosulam showed statistically the lowest phenology average compared to other treatments, possibly because got low weed control (Table 2). S-metolachlor + imazethapyr, S-metolachlor + fomesafen and S-metolachlor + diclosulam a lower NDVI index, it was a better weed control, because lower weed coverage in the plots (Table 2).

Materials and Methods

Location

The experiment was performed in a commercial soybean field located in Brejo, Maranhão state, Brazil (03°42'11'' South, 42°56'19' West). It has a climate of hot and humid tropical, with annual rainfall of 1,600 to 2,000 mm, mean temperature of 27ºC, and mean relative humidity of 76%. The rainy season usually occurs between January and June 2022. The meteorological database is presented in Fig. 1.

During the off-season from May to December 2021, the forage species *Panicum maximum* cv. BRS Tamani was planted in the agricultural plot as ground cover, using 5 kg ha^{-1} of scarified seeds and sowing in the open field. The cover crop was thinned with a knife roller in two sequential operations, carried out between October and December 2021. Then, in December 2021, the plot was burned with glyphosate + 2,4-D (4,397.10 g a.i. ha^{-1} + 1,000.00 g a.i. ha^{-1}). After 20 days, the straw amount was estimated in 30 random samplings, with a square of 0.5 m x 0.5 m whose estimate was 11 t ha^{-1} of straw.

The no-till soybean seeding under *Panicum maximum* cv. BRS Tamani was performed in early February 2022, using the cultivar M8644 IPRO with 16 seeds per meter and an average cycle of 130 days.

Treatments screening

The experiment was conducted in randomized block design and striped arrangement, composed of 8 treatments and 5 repetitions. The treatments consisted in no-treatment, S-metolachlor + imazethapyr (1,200.00 g a.i. ha^{-1} + 100.00 g a.e. ha^{-1}, respectively), S-metolachlor + fomesafen (1,035.66 g a.i. ha^{-1} + 227.70 g a.e. ha^{-1}, respectively), S-metolachlor + diclosulam (1.200.00 g a.i. ha^{-1} + 29.40 g a.i. ha^{-1}), imazethapyr + diclosulam (100.00 g a.e. ha^{-1} + 29.40 g a.i. ha^{-1}), imazethapyr + flumioxazin (100.00 g a.e. ha^{-1} + 50.00 g a.i. ha^{-1}), pyroxasulfone + flumioxazin (90.00 g a.i. ha^{-1} + 60.00 g a.i. ha^{-1}) and pendimethalin (1,137.50 g a.i. ha^{-1}). The spraying was carried out the day after soybean seeding, directed to the straw, using a CO_2 pressurized knapsack sprayer, equipped with six nozzles and 3 meters in size. The tips were single fan type, 2 bar pressure, and 150 L ha^{-1} spraying rate.

Weed conventional surveys

The weed survey was performed in two phases: phase 1 – before soybean seeding (3 days before burn operations); phase 2 – post soybean seeding (25 days after pre-emergence herbicides spraying – DAS). In the first phase, one hundred samplings were performed using a square (1.0 m x 1.0 m), in a 20 m x 20 m transect, in 10 routes and 10 sampling points per route. In post soybean seeding a survey was made in experimental plots of each treatment, in a sample subarea of 9 m^2.

During the sampling process, we identified the weeds using specialized literature and quantified them to calculate phytosociological indices and control using the following equations:

$$\text{Eq. 1: Relative density (RD)} = \frac{\text{species density} \times 100}{\text{total species density}}$$

$$\text{Eq. 2: Relative frequency (RF)} = \frac{\text{species frequency} \times 100}{\text{total species frequency}}$$

$$\text{Eq. 3: Relative abundace (RA)} = \frac{\text{species abundace} \times 100}{\text{total species abundace}}$$

$$\text{Eq. 4: Importance Value Index (IVI)} = \text{RD} + \text{RF} + \text{RA}$$

$$\text{Eq. 5: Weed control} = \frac{(\text{notreatment density} - \text{treatment density})}{\text{notreatment density}} \times 100$$

The control was categorized in none to poor (0 to 40%), fair (41 to 60%), sufficient (61 to 70%), good (71 to 80%), very good (81 to 90%), and excellent (91 to 100%).

Crop evaluations

The soybean herbicide selectivity was analysed at 25 DAS using a scale model based on visual symptomatology. The scores ranged from 1 to 9, which grade 1 (none symptoms) and 9 (crop death). Also, we evaluated plant density, phenology, and NDVI index with greenseaker. For this, two central lines of each treatment were used in 2 meters size and 5 repetitions.

Statistics methods

The phytosociological survey database and weed control were analysed by descriptive statistics methods. The spatial weed variability was analysed for goestatisticals methods in weed density for the botanical class. The Degree of Spatial Dependence (DSD) was classified, as weak (DSD<25%), moderate (25<DSD<75%), and strong (DSD>75%). While soybean growth and phytotoxicity were analysed for F (p<0.05) and Tukey tests.

Conclusion

We identified 23 weed species distributed in 22 genera and 15 botanical families, majority of eudicotyledonous botanical class (78.2%), annual life cycle (56.5%), and sexual reproduction (100%).

The integrated weed management was effective in herbicide-resistant weed control, except *Euphorbia heterophylla*. The treatments recommended included S-metolachlor combinations with fomesafen, imazethapyr, and diclosulam; and also pyroxasulfone + flumioxazin.

The *Panicum maximum* cv. BRS Tamani straw, estimated in 11 t ha^{-}1, may have negatively influenced herbicides most lipophilics, and slower movement, such as pendmethalin.

Conflict of interest

The authors declare that there is no conflict of interest.

Acknowledgments

The Coordination for the Advancement of Higher Education Personnel (CAPES) provided a scholarship for the first author. The Foundation for the Support of Scientific and Technological Research of Maranhão (FAPEMA), with financial support under code 750/22. The Soybean Producers Association of Maranhão, Meio-Norte branch, provided logistical assistance.

References

Adegas FS, Correua NM, Silva AE, Concenço G, Gazziero DLP, Dalazen, G (2022)

Glyphosate-resistant (GR) soybean and corn in Brazil: past, presente, and future. Advances in Weed Science, 40: e0202200102.

Adegas FS, Vargas L, Gazziero DLP, Karam D (2017) Impacto econômico da resistência de plantas daninhas a herbicidas no Brasil. Londrina, Embrapa Soja. 11p. (Circular, 132).

Albrecht JP, Lorenzetti JB, Albrecht LP, Danilussi MTY, Barroso AMM, Silva AFM (2022) Eficácia de herbicidas no controle Spermacoce verticillata e seletividade para as plantas de milho. Weed Control, 21: e202200769.

Albuquerque JAA, Melo VF, Soares MBB, Finoto EL, Siqueira RHS, Martins AS (2021) Incidência de plantas daninhas após a colheita da soja em sistemas de plantio direto e rotação de culturas de plantio convencional no cerrado de Roraima. Planta Daninha 7: 313-32.

Bottcher AA, Albrecht AJP, Albrecht LP, Kashivaqui ESF, Cassol M, Souza CNZ, Wagner FG, Silva AFM (2022) Herbicide efficacy in the fall management of *Richardia brasiliensis, Commelina benghalensis, Conyza sumatrensis* and *Digitaria insularis*. Bioscience Journal. 38: e38025.

Carbonari CA, Gomes GLGC, Krenchinski FH, Simões OS, Castro EB, Velini ED (2016) Dynamics and efficacy of sulfentrazone, flumioxazin, and isoxaflutole herbicides applied on eucalyptus harvest residues. New Forests, 51: 723-37.

CONAB – Companhia Nacional de Abastecimento (2023) Acompanhamento da Safra Brasileira de Grãos, Brasília, Safra 2022/23, Décimo segundo levantamento. Available in: <http://www.conab.gov.br >. Acessed in: Aug of 2023.

Coradin J, Braz GBP, Machado FG, Silva AG, Sousa JVA (2019) Herbicidas aplicados em pré-emergência para o controle de milho voluntário e capim-amargoso. Revista Científica Rural. 3: 51-64.

Cornelius CD, Bradley KW (2017) Carryover of common corn and soybean herbicides to various cover crop species. Weed Technology. 31: 21–31

Cruz LR, Ferreira L, Canuto RSO, Canuto MFO (2019) Levantamento fitossociológico de plantas daninhas e controle de *Cyperus rotundus* L. com glifosato em pré-semeadura de feijão. Agrarian Academy. 6: 197-205.

Ferreira ECA, Mendonça CG, Montanari R, Possamai ACS, Mendonça CG (2013) Espacialização do banco de sementes de plantas daninhas sob diferentes manejos de cana-de-açúcar em Rio Brilhante, Mato Grosso do Sul. Bioscience Journal. 29: 1458-1468.

Furtado JAL, Almeida EIB, Oliveira LBT, Santos AC, Da Costa TV, Da Silva MS, Souza JBC, Sousa WS, Ponte IS, Freitas JRB (2022) Spatial relation of weed competition and soil fertility in soybean farming. Australian Journal of Crop Science. 16: 899-906.

Gazola T, Gomes DM, Belapart D, Dias MF, Carbonari CA, Velini ED (2021) Selectivity and residual weed control of pre-emergent herbicides in soybean crop. Revista Ceres. 68: 219-229.

Golubev AS (2021) Weed control with diclosulam in soybean. Emirates Journal of Food and Agriculture. 33: 187-193.

Heap I, Duke SO (2018) Overview of glyphosate-resistant weeds worldwide. Pest Management Science. 74: 1040–1049.

Jank L, Santos MF, Braga GJ. (2021) Capim-BRS Tamani (*Panicum maximum* Jacq.) Available in: <https://www.infoteca.cnptia.embrapa.br/infoteca/handle/doc/1149054> Acessed in: Oct of 2022.

Jones EAL, Andres RA, Dunne JC, Leon RG, Everman WE (2022) Utilization of image-based spectral reflectance to detect herbicide resistance in glufosinate-resistant and glufosinate-susceptible plants: a proof of concept. Weed Science. 71: 11-21.

Khalil Y, Flower K, Siddique KHM, Ward P (2019) Rainfall affects leaching of pre-emergent herbicide from wheat residue into the soil. Plos One. 14: e0210219.

Kumar M, Das TK, Yaduraju NT (2012) An integrated approach for management of *Cyperus rotundus* (purple nutsedge) in soybean–wheat cropping system. Crop protection. 33: 74-81.

Küpper A, Borgato EA, Patterson EL, Gonçalves Neto A, Nicolai M, Carvalho SJP, Nissen S, Gaines TA, Christoffoleti PJ (2017) Multiple resistance to glyphosate and acetolactate synthase inhibitors in Palmer amaranth (*Amaranthus palmeri*) identified in Brazil. Weed Science, 65: 317-326.

López-Ovejero RF, Soares DJ, Oliveira WS, Fonseca LB, Berger GU, Soteres JK & Christoffoleti PJ (2013) Residual herbicides in weed management for glyphosate resistant soybean in Brazil. Planta Daninha, 31: 947-59.

Machado AB, Trezzi MM, Vidal RA, Patel F, Cieslik LF, Desbastiani F (2015) Rendimento de grãos de feijão e nível de dano econômico sob dois períodos de competição com *Euphorbia heterophylla*. Planta Daninha. 33: 41-48.

Matte WD, Cavalieri SD, Pereira, CS, Ikeda FS, Costa WB (2019) Residual activity of diclosulam applied to soybean on cotton crop in sucession. Planta Daninha. 37: 1-11.

Matte WD, Oliveira Júnior RS, Constantin J, Mendesa, RR (2022) Controle de capim-amargoso após a aplicação de herbicidas em pré-emergência em solo com níveis crescentes de palhada de soja e milho. Weed Control Journal. 20: e202100729.

Muller TC, Boswell BW, Mueller SS & Steckel LE (2017) Dissipation of fomesafen, saflufenacil, sulfentrazone, and flumioxazin from a Tennessee soil under filed conditions. Weed Science, 62: 664-671.

Nichols V, Verhulst N, Cox R, Govaerts, B (2015) Weed dynamics and conservation agriculture principles: A review. Field Crops Research. 183: 56–68.

Oliveira Neto AM, Constantin J, Oliveira Júnior RS, Guerra N, Braz GBP, Vilela LMS, Botelho LVP, Ávila LA (2013) Sistemas de dessecação em áreas de trigo no inverno e atividade residual de herbicidas na soja. Revista Brasileira de Herbicidas 12: 14-22.

Ovejero RFL, Picoli Junior GJ, Takano HK, Palhano M, Westra P (2019) Residual herbicides in Roundup Ready soybean: a case study in multiple years and locations with *Ipomoea triloba*. Ciencia e Agrotecnologia, 43: 1-10.

Palma-Bautista C, Rojano-Delgado AM, Vázquez-Garcia JG, Yanniccari M, De Prado R (2020) Resistance to fomesafen, imazamox and glyphosate in *Euphorbia heterophylla* from Brazil. Agronomy. 10: 1573.

Patel F, Trezzib MM, Nunes AL, Bittencout HVH, Diesel F, Pagnoncelli Junior FB (2023) The straw presence preceding soybean crop increases the persistence of residual herbicides. Advanced Weed Science. 41: e020200051.

Pazuch D, Trezzi MM, Guimarães ACD, Barancelli MVJ, Pasini R, Vidal RA (2017) Evolution of natural resistance to glyphosate in morning glory populations. Planta Daninha. 35: 1-9.

Sharma K, Punnia SS, Mehta AK, Leharwan, M (2021) Bioefficacy of imazethapyr applied alone and in combination with other herbicides in black gram and their residual effect on succeeding pearl-millet and sorghum crops. Legume Research-An International Journal. 7: 1-7.

Silva DA, Abuquerque JAA, Alves JMA, Rocha PRR, Medeiros RD, Finoto E L, Menezes PHS (2018) Characterization of weed in rotated area of maize and cowpea in direct planting. Scientia Agropecuária. 9: 7-15.

Silva MS, Furtado JAL, Castro JQ, Santos IL, Almeida EIB, Oliveira LBT, Sousa WS, Araújo RCA (2021) Weed control and selectivity of different pre-emergence active ingredients in a soybean crop. Agronomia Colombiana. 39: 392-404.

Silva MS, Costa TV, Furtado JAL, Souza JBC, Da Silva EA, Ferreira LS., Silva CAAC, Almeida EIB, Sousa WS, Oliveira LBT, Freitas JRB, Oliveira JT (2021) Performance of pre-emergence herbicides in weed competition and soybean agronomic components. Australian Journal of Crop Science. 15: 610-617

Soltani N, Dille JA, Burke IC, Everman WJ, VanGessel MJ, Davis VM, Sikemma PH (2017) Perspectives on potential soybean yield losses from weeds in North America. Weed Technology. 31: 148-154.

Summers H, Karsten HD, Curran W, Malcolm GM (2021) Integrated weed management with reduced herbicides in a no-tilldairy rotation. Agronomy Journal. 113: 3418–3433.

Vargas L, Nohatto MA, Agostinetto D, Bianchi MA, Paula JM, Poliodoro E, Toledo RE (2013) Práticas de manejo e a resistência de Euphorbia heterophylla aos inibidores da ALS e tolerância ao glyphosate no Rio Grande do Sul. Planta Daninha. 31: 427-432.

Whalen DM, Bish MD, Young BG, Hager AG, Conley SP, Reynolds DB, Bradley KW (2019) Evaluation of cover crop sensitivity to residual herbicides applied in the previous soybean [*Glycine max* (L.) Merr.] crop. Weed Technology. 2: 312–320.

Zangoueinejad R, Sirooeinejad B, Alebrahim MT, Alebrahim, MT (2022) Integrated use of herbicides and mulching for sustainable control of purple nutsedge (*Cyperus rotundus*) in a tomato crop. Sustainability 14: 12737.