Scientific Electronic Archives
ISSN 2316-9281
Issue ID: Vol.19 (5), Set/Oct 2026, p. 1-8
DOI: http://dx.doi.org/10.36560/19520262246
+ Corresponding author: andreza.maciel@alu.ufc.br

Early pre-emergence control of Spermacoce sp. in soybean fields

Sabrina Nascimento Teixeira [1] , Edmilson Igor Bernardo Almeida [1], Lourrana Rhavenna Diogo Silva [1] , Andreza Maciel de Sousa [2] +, Bruno Ferreira da Silva [1] , Aldair de Souza Medeiros [3], Paulo Alexandre Fernandes Rodrigues de Melo [4], Washington da Silva Sousa [1]

[1] Universidade Federal do Maranhão
[2] Universidade Federal do Ceará
[3] Universidade Federal do Piauí
[4] Universidade Estadual do Maranhão

Abstract. The buttonweed (Spermacoce sp.) management is currently one of the main soybean yield gaps in Brazil. As it is a glyphosate-tolerant weed the adoption of early control practices are very important. Given this, the objective this study was to evaluate the performance of pre-emergent and post-emergent herbicides, alone or mixed, on the early button[eed control in a soybean field. The experiment was conducted in a commercial soybean farm, located in Mata Roma, Maranhão, Brazil. The area was selected due to its history of successive glyphosate use and reports of broomweed selection for at least 10 years. The experiment was designed in randomized blocks with 10 treatments and 4 replicates. The treatments consisted of the control (without herbicide), glyphosate, glyphosate + glufosinate, glyphosate + flumioxazine + pyroxasulfone, glyphosate + flumioxazine + imazethapyr, glufosinate + flumioxazine + pyroxasulfone, glufosinate + flumioxazine + imazethapyr, flumioxazine + pyroxasulfone, and flumioxazine + imazethapyr. We evaluated the buttonweed control, and phytotoxicity, density, plant height, NDVI index, total chlorophyll index, and soybean yield. We found buttonweed glyphosate-tolerant populations to the 1,500 (1st application) + 1,620 g a.e. ha^{-1} (2nd application) applications, resulting in 59% yield losses. The combinations of glyphosate with glufosinate and flumioxazine increased the buttonweed control compared glyphosate alone. The application of flumioxazin (50 to 60 g a.i. ha^{-1}) in mixture with glufosinate (500 g a.i.) is effective for buttonweed control in soybean pre-planting, preserving a range control greater than 80% and a safety soybean yield.
Keywords: Glycine max (L.) Merr, flumioxazin, glufosinate, glyphosate-tolerant weed, herbicide mixture.

Introduction

The soybean crop [Glycine max (L.) Merr.] is one of the main sources of protein in world, playing an important role in human and animal nutrition. There is a wide availability of cultivars adapted to different climate and soil conditions, which validates Brazil as the world's leading producer, with a planted area of 47 million hectares and a production of 169 million tons of grain in the 2024/2025 harvest (CONAB, 2025).

Weed management is an important gap in soybean productivity, because, when not properly controlled, weeds compete for physical space, water, light, and nutrients, causing significant losses (Pereira et al., 2019). In this context, buttonweed (*Spermacoce* sp.) is actually in brazilian soybean commercial fields an undesirable weed due to its biological characteristics and hard herbicides control, especially to glyphosate (Diesel et al., 2018).

The buttonweed is a weed belonging to the Rubiaceae family, native to America, a rustic perennial that spreads easily (Castilho, Forti and Monquero, 2022), It can germinate in low light conditions (Gallon et al., 2019), adapts well to dry periods (Nepomuceno et al., 2018), and is glyphosate-tolerant species (Albrecht et al., 2022). The glyphosate is main herbicide used for weed control in soybean farming worldwide, in this context, the exclusive and repetitive glyphosate application, sometimes in high doses, has led to an increase in the selection of glyphosate-tolerant and glyphosate-resistant species in soybean crops in Brazil (Adegas et al., 2022).

The tolerance of buttonweed to glyphosate occurs mainly due to the low translocation capacity of this herbicide in plant tissue. Therefore, glyphosate does not move efficiently and does not cause the expected inhibitory effect on the plant, especially in more advanced phenological stages (Fadin et al., 2018). Thus, the application of post-emergence herbicides in the early buttonweed phase, or pre-emergence measures targeting the seed bank can be effective for this species control (Moreira et al., 2024; Furtado et al., 2025;).

In this regard, glyphosate combinations with flumioxazine and glufosinate has been reported as an alternative for the chemical control of buttonweed in soybean crops (Ponte et al., 2024; Kalsing et al., 2022). However, there are still few studies on the performance of these mixtures and their isolated effects in pre-planting soybeans, as a sequential spraying method in traditional glyphosate management. Thus, the sequential herbicides application and early pre-emergence control from flumioxazin may allow a higher efficiency.

In addition, early control can reduce the selection pressure of glyphosate in soybeans post-emergence control, when alternatives for broad weed control are scarce, notably in Roundup Ready® soybean cultivations (glyphosate-tolerant). Given the above, the hypothesis of the present study is that early, rotated, combined, and sequential herbicides spraying is effective strategy for buttonweed control.

The objective this study was to evaluate the pre-emergent and post-emergent herbicides performance, alone or mixed, on the early buttonweed (*Spermacoce* sp.) control in soybean pre-planting.

Material and Methods

Study location

The experiment was conducted during January and April 2024 on the commercial soybean farm located in Mata Roma, Maranhão, Brazil, at geographical coordinates 3º40'38.21"S 43°11'5889" W. This city is located in the Cerrado biome, C2W2A'a' climate (sub-humid) with an average temperature of 27 ºC and annual rainfall of 1,600 to 2,000 mm.

The meteorological database during the study showed an average monthly rainfall of 338.62 mm, total accumulated rainfall of 1,140 mm, maximum temperature of 33 °C, and minimum temperature of 24 °C (INMET, 2024). The Figure 1 shows the rainfall data measured by a rain gauge located in the experimental area during the study (Figure 1).

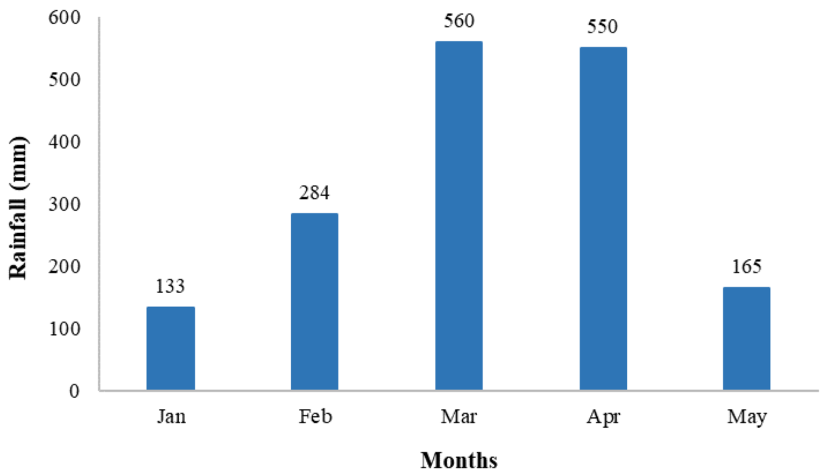

Figure 1. Rainfall data (mm) recorded in the experimental area during the study. Mata Roma, Maranhão, Brazil, 2024.

The soil was classified as Yellow Argisol typical distrocoesic, according to the Brazilian Soil Classification System (Santos et al., 2018). Chemical analysis of the 0-20 cm layer showed the following results: pH – 5.2; phosphorus (P) – 1.9 mg dm^{-3}; organic matter (OM) – 1.9%; sum of bases (SB) – 2.0 cmol dm^{-3}; base saturation (V) – 54%.

The experimental area was selected due to its history of exclusive glyphosate control for at least ten years. During the off-season, between May and December 2023, the experimental area was subsoiled, harrowed, and cultivated with 'ADR 300' millet, broadcast seeded at a rate of 15 kg of seeds per hectare. This cover crop and the remaining weeds were initially desiccated with 1,500 g a.e. ha^{-1} of glyphosate (Zapp QI 620®) to fifteen days before soybean planting. Planting took place in the second week of January 2024, using the Brasmax Dominio IPRO cultivar, with a planting density of 25 seeds per meter.

Statistical analysis

The experiment was conducted in a randomized block design, with teen treatments and four replicates. The treatments consisted of the control (without herbicide), glyphosate (1,620 g a.e. ha^{-1}; Templo®), glufosinate (600 g i.a. ha^{-1}; Finale®), glyphosate + glufosinate (1,350 g a.e. ha^{-1} + 500 g a.i. ha^{-1}; Templo® + Finale®), glyphosate + flumioxazine + pyroxasulfone (1,350 g a.e. ha^{-1} + 60 g a.i. ha^{-1} + 90 g a.i. ha^{-1}; Templo® + Kyojin®), glyphosate + flumioxazine + imazethapyr (1,350 g a.i. ha^{-1} + 50 g a.i. ha^{-1} + 106 g a.i. ha^{-1}; Templo® + Zethamaxx®), glufosinate + flumioxazine + pyroxasulfone (500 g i.a. ha^{-1} + 60 g i.a. ha^{-1} + 90 g i.a. ha^{-1}; Finale® + Kyojin®), glufosinate + flumioxazine + imazethapyr (500 g a.i. ha^{-1} + 50 g a.i. ha^{-1} + 106 g e.a. ha^{-1}; Finale® + Zethamaxx®), flumioxazine + pyroxasulfone (60 g a.i. ha^{-1} + 90 g a.i. ha^{-1}; Kyojin®), flumioxazine + imazethapyr (50 g a.i. ha^{-1} + 106 g e.i. ha^{-1}; Zethamaxx®).

The herbicides were applied four days before soybean planting, following a first application of 1,500 g a.i. of glyphosate (Zap QI 620®) applied to fifteen days before planting. All treatments, including the control, received a first glyphosate application.

The treatments were applied with a CO2-pressurized backpack sprayer equipped with a 3-meter central bar and six spray nozzles. The spray tips were fan-type, with a working pressure of 2 Bar and a spray rate of 100 L ha^{-1}. Spraying was carried out between 8:30 and 9:30 a.m., at a temperature of 27 °C, relative moisture of 81%, and average wind speed of 5.7 km h^{-1}, in accordance with ISO 5682-1:1996 guidelines. The buttonweed was arranged at a density of 4 pl m^{-2}, predominantly in the early stage, with 2 to 4 leaves. However, there was some adult plants and regrown plants.

Variables analyzed

The buttonweed control was evaluated at 15, 30, 45, and 75 days after treatments application, with visual scores assigned on a scale of 0 to 100% control, according to SBCPD (1995) guidelines for the installation, evaluation, and analysis of herbicide experiments. The results were nominally classified as, without or poor (0 to 40%), fair (41 to 60%), sufficient (61 to 70%), good (71 to 80%), very good (81 to 90%), and excellent control (91 to 100%). Its were considered effective to treatments with equal or greater than 80% control (Gonese and Weber, 1998; SBCPD, 1995).

The treatments selectivity on the Brasmax Dominio IPRO soybean cultivar was estimated at 15, 30, and 45 DAT using a conceptual phytotoxicity scale from the European Weed Research Community (EWRC, 1964). Visual assessments of phytotoxicity symptoms were performed, expressed by leaf chlorosis, branch and leaf necrosis, branch and leaf curling, over-sprouting, and reduced soybean growth. Scores ranged from 0 (no symptoms) to 100% (plant death).

The soybean crop stand was evaluated at 15, 30, and 45 days after treatments application (DAT) for plant height (distance between the soil surface and the plant apex, in cm), phenology (count of open trifoliates), plant density (number of plants per meter), Normalized Difference Vegetation Index - NDVI (measured with an active light optical sensor, GreenSeeker®), total chlorophyll index (measured with a chlorophyll sensor, ClorofiLOG®). The experimental plot measured 3 m x 6 m, totaling 72 m² per treatment.

Soybean yield was estimated 105 days after planting, from the manual harvest in a sample of 7 m² by replication and 28 m² by treatment. Subsequently, the plants were subjected to mechanized threshing, cleaning, and weighing. The yield results were estimated in kg ha^{-1}.

Variables analyzed

The data were submitted to the Shapiro-Wilk residual normality test ($p \leq 0.05$), variance analysis (F test), and when the contrasts between the means were significant ($p \leq 0.05$), the Duncan test was applied for treatment comparations.

Results and discussion

The use of glyphosate alone ((1,620 g a.e. ha^{-1}) showed a low control (20 to 28%) and was statistically similar to the control (without herbicide) at all evaluation times (15, 40, 45, and 75 DAT) (Figure 2).

The low glyphosate performance alone is consistent with the results reported on the tolerance of buttonweed to this herbicide (Fadin et al., 2018) and, despite being applied sequentially (1,500 g a.i. ha^{-1} + 1,620 g a.e. ha^{-1}). The control percentages were less than 30%, therefore, significantly below the recommended control in herbicide tests (≥80%). In this context, Fadin et al. (2018) explained that the tolerance of buttonweed to glyphosate results from the low absorption and translocation of the herbicide in the plant, especially after the development of the fourth leaf, when there is a significant formation of leaf trichomes.

Therefore, glyphosate becomes ineffective when used alone to control this species. Even when applications of this herbicide are carried out in sequence, as in the present study (1,500 + 1,620 g a.e. ha^{-1}). On the other hand, the isolated use of glufosinate (600 g a.i. ha^{-1}) or combined to glyphosate (500 + 1,350 g a.i. or a.e. ha^{-1}) proved to be more effective and statistically superior to the isolated glyphosate application (1,500 g a.e. ha^{-1}) at 15 (52 and 56%), 30 (52 and 58%), 45 (50 and 60%), and 75 (53 and 46) days after treatments (Figure 2). However, although these results were superior to the use of glyphosate alone (1,620 g a.e. ha^{-1}), the control percentages were below the recommended range (≥80%). This was possibly due to the without pre-emergent action these herbicides on the soil seed bank, which increases the occurrence of new germination flows and, consequently, competition throughout the soybean crop.

The results obtained with glufosinate indicated an additive effect on glyphosate combination, which may be related to its mode of action on plant tissue, with no or very low absorption and translocation in the plant. This results in lesions a few days after application. In this context, were obtained percentages 30 to 40% higher than the glyphosate alone (1,620 g a.e. ha⁻¹), The glyphosate is a systemic herbicide and, therefore, needs to translocate in the plant to convey its inhibitory effects (Ponte et al., 2024). Therefore, as the buttonweed has a differential capacity for absorption and translocation of systemic herbicides, these symptoms do not express themselves as expected over time (Diesel et al., 2018).

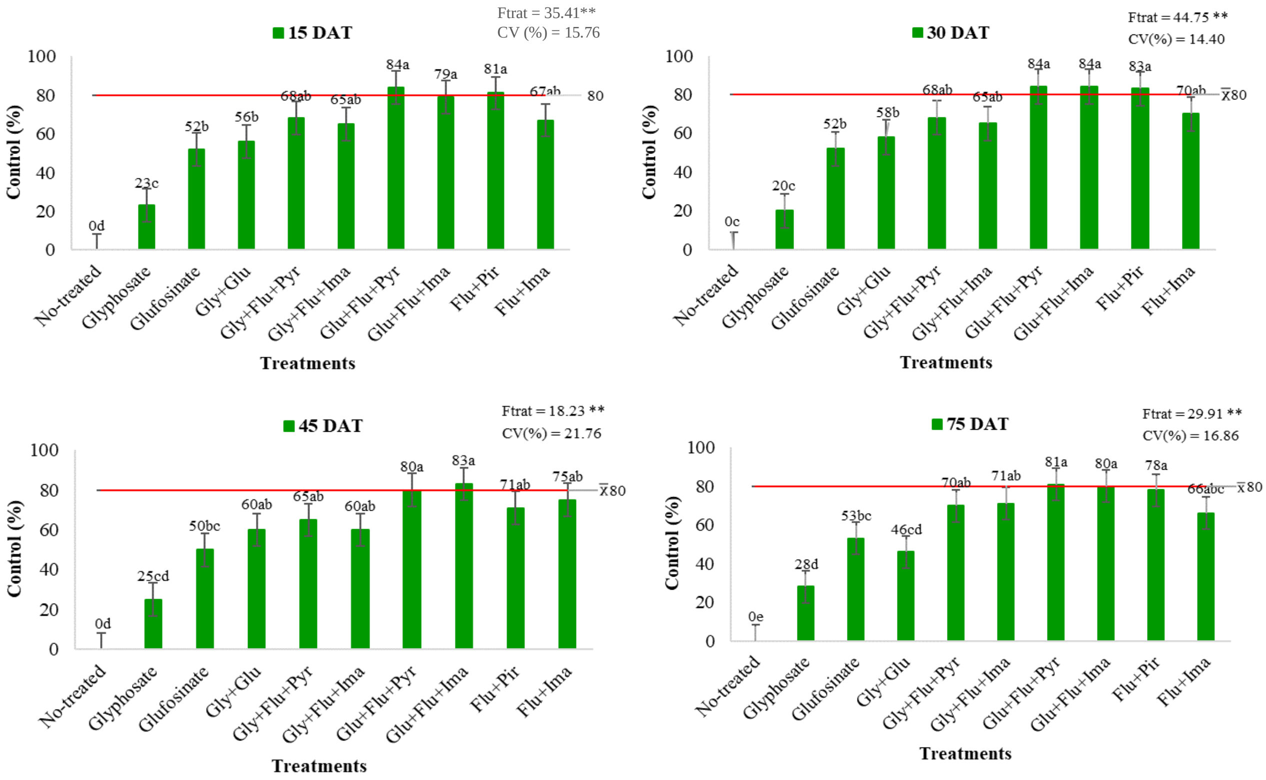

Figure 2. Buttonweed control at 15 (Fig. A), 30 (Fig. B), 45 (Fig. C), and 75 (Fig. D) days after treatment application in soybean crops.

In addition, the glufosinate application in the buttonweed early stage resulted in greater susceptibility of the target species. This is related to the contact action mode, whose damage is faster and more effective in young tissues (Fadin and Monquero, 2019).

The glufosinate and flumioxazine combinations were the most effective treatments in this study (Figure 2). The control percentages for the use of glufosinate + flumioxazine + pyroxasulfone and glufosinate + flumioxazine + imazethapyr were respectively of 84 and 79% (15 DAT), 84 and 84% (30 DAT), 80 and 83% (45 DAT), 80 and 81% (75 DAT). These reached the recommended control range for herbicide tests (≥80%).

In this context, it is likely that the pre-emergent and post-emergence control of flumioxazin, as well as its synergism with glufosinate for the control of buttonweed in post-emergence (Santos et al., 2025) were the fundamental aspects for this high efficiency obtained in the present study (≥80%). These performances were consistent with the control reported by Ponte et al. (2024), Silva et al. (2025) in study combinations of glufosinate and protoporphyrin oxidase (PROTOX) inhibitor herbicides.

The flumioxazine and glufosinate combinations remained with a control greater than 80% until 75 days after treatments application (Figure 2). Thus, demonstrating also an efficient pre-emergent control. Therefore, the use of flumioxazin proves to be a promising alternative for the buttonweed control from the seed bank (pre-emergence) to advanced phenological stages (post-emergence).

The performances obtained with glufosinate + flumioxazine (+ imazethapyr or + pyroxasulfone) combinations were statistically similar to the glyphosate + flumioxazine (+ imazethapyr or + pyroxasulfone) and flumioxazine + imazethapyr (or + pyroxasulfone) combinations (Figure 2). However, glyphosate combinations obtained results below 80%, which is not a safe range. This demonstrates the buttonweed glyphosate-tolerance even when this herbicide is applied in combination with other mechanisms and modes of action.

One factor that may have influenced the low glyphosate performance mixed to glufosinate and flumioxazine is the occurrence of lesions in plant tissue caused from contact herbicides (Brustolin et al., 2020). This statistically contrasts with the results obtained with glufosinate + flumioxazine, which have a contact action mode and expressed a synergistic control reaction.

Regarding soybean population, different behaviors were observed, with the control (without herbicide) and glyphosate alone, resulting in statistically lower averages than the other treatments (p<0.05). Notably when compared to glufosinate + flumioxazine (+ imazethapyr or + pyroxasulfone) (Figure 3A).

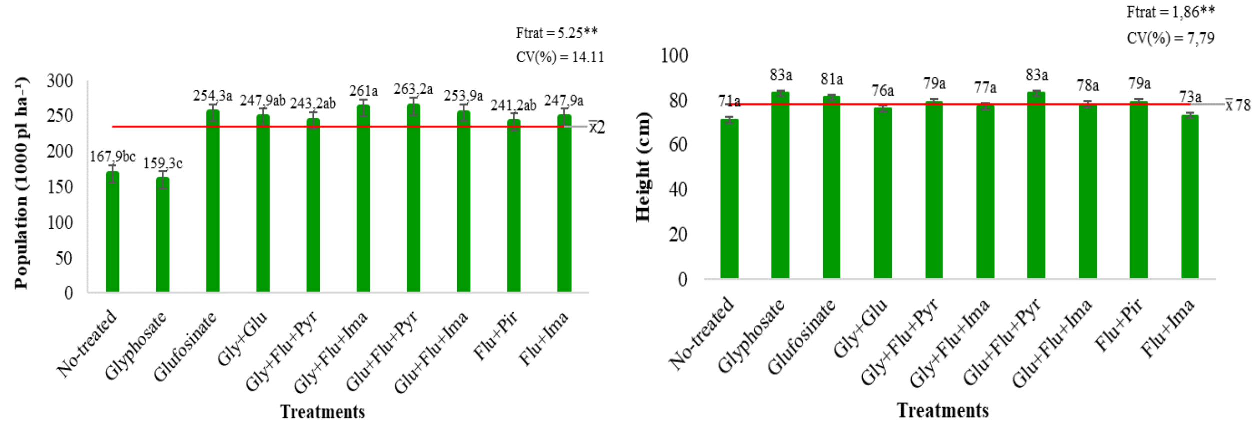

Figure 3. Population (Fig. A) and soybean plant height, 75 days after treatment application, in soybean crops.

This can be explained by the differential control efficiency of buttonweed, whose best-performing treatments showed more uniform stands, with less plant mortality and, therefore, less compromised by competition with buttonweed and other weeds. In contrast, the treatments with lower control efficiency, such as the control (without herbicide) and the use of glyphosate alone (1,620 g a.e. ha^{-1}), the opposite occurred.

However, despite the interference with plant density in the stand, competition between buttonweed and soybeans did not result in statistically significant differences in plant height at 75 DAT (Figure 3B); phytotoxicity, NDVI, and total chlorophyll at 15, 30, and 45 DPA (Figures 4A and 4B).

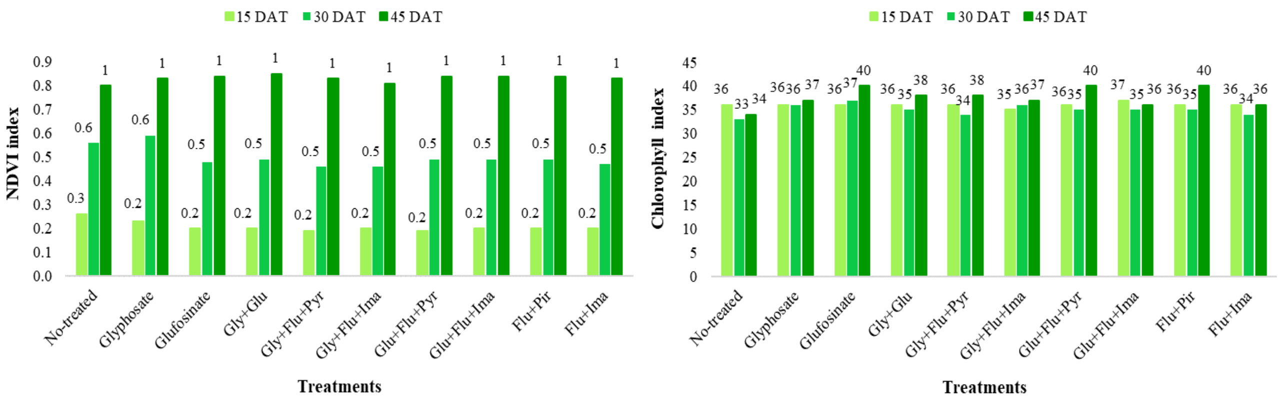

Figure 4. NDVI index (Fig. A) and chlorophyll at 15, 30, and 45 days after treatment application in soybean crops.

The phytotoxicity rates were estimated to 0% for all treatments and are not plotted in the graph. This result shows a high selectivity of the all herbicides analyzed on the soybean crop, cultivar Brasmax Dominio IPRO. These results were corroborated with others non-significant effects of the treatments on the stand variables (height, NDVI, and chlorphyll) (Figures 3B, 4A, and 4B). These variables also appeared to be unaffected by competition with buttonweed.

On the other hand, yield showed statistically significant differences among the treatments analyzed ($p<0.05$), with the best results being compatible with the highest buttonweed control. Thus, glufosinate + flumioxazine (+ pyroxasulfone or + imazethapyr) applications resulted in the best yield performances, estimated at 2,975 to 3,012 kg ha^{-1} (Figure 5).

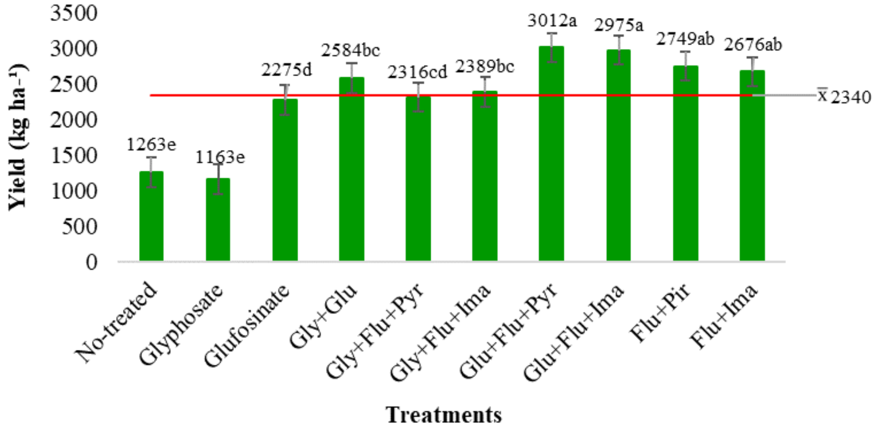

Figure 5. Soybean yield, cultivar Domínio 84I86 IPRO, under different herbicide treatments applied.

The glyphosate alone application (1,620 g a.e. ha^{-1}) resulted in 59% of yield losses. The glufosinate alone application resulted in 24%, while glyphosate + glufosinate combination resulted in 14% of yield losses (Figure 5). For flumioxazine + pyroxasulfone and flumioxazine + imazethapyr were estimated 9 to 11% of yield losses. Thus, buttonweed showed greater susceptibility to the use of flumioxazine compared to the use of glyphosate and glufosinate, when both are alone or combined.

The glufosinate alone showed statistically superior results to the glyphosate alone (+1,112 kg ha^{-1}), and was statistically similar to glyphosate + glufosinate (-309 kg ha^{-1}), and glyphosate + flumioxazine + imazethapyr (- 41 kg ha^{-1}) (Figure 5). Its supports the additive effect of glufosinate on glyphosate, as well as the synergistic effect on flumioxazine combinations.

Thus, it is clear that flumioxazin performs better in glufosinate combinations for the buttonweed early management. This may be related to the mode of action (both contact herbicides) and synergism of their inhibitory effects on the photosynthesis. These results corroborate those of Brunetto et al. (2023), who obtained satisfactory results when combining PPO-inhibiting herbicides, such as flumioxazin and saflufenacil, with glufosinate for the broadleaf weed control.

On the other hand, pyroxasulfone and imazethapyr application had very little effect on the buttonweed control and yield estimates, possibly because it has a more spectrum on monocotyledonous weeds, as reported by SILVA et al. (2024). Therefore, it is not effective alternatives for the alone pre-emergence control of buttonweed. For them to act effectively, it is important to combine these herbicides with flumioxazine.

Conclusion

We found buttonweed glyphosate-tolerant populations to the 1,500 (1st application) + 1,620 g a.e. ha^{-1} (2nd application) applications, resulting in 59% yield losses. The combinations of glyphosate with glufosinate and flumioxazine increased the buttonweed control compared glyphosate alone, but is not recommended because obtained a range control below 80%.

The application of flumioxazin (50 to 60 g a.i. ha^{-1}) in mixture with glufosinate (500 g a.i.) is effective for buttonweed control in soybean pre-planting preserving a range control greater than 80% and a safety soybean yield.

Acknowledgments

Thanks to the “Fundação de Amparo à Pesquisa e ao Desenvolvimento Científico e Tecnológico do Maranhão (FAPEMA)” for the financial support, code “FAPEMA Universal 750/22”, and to “Aprosoja Maranhão” for the operational support.

References

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

ALBRECHT, A. J. P. et al. Eficácia de herbicidas no controle Spermacoce verticillata e seletividade para as plantas de milho. *Weed Control Journal*, v. 21, p. e202200769, 2022. DOI: http://dx.doi.org/10.7824/wcj.2022;21:00769

Bento, K. F., Carniel, E., Raimundo, C. B., Rocha, R. R., & Schoninger, E. L. (2020). Availability of boron in clayey and sandy soil due to the application of different borated sources in soybean cultivation. *Scientific Electronic Archives*, *13*(11), 51–55. https://doi.org/10.36560/131120201191

BRUNETTO, L. et al. Manejo químico de caruru-roxo (Amaranthus hybridus) com herbicidas aplicados em pré e pós-emergência. *Weed Control Journal*, v. 22, p. e202300790, 2023. DOI: http://dx.doi.org/10.7824/wcj.2023;22:00790

BRUSTOLIN, D. B. et al. Associação de herbicidas como alternativa no controle e na avaliação do desempenho fisiológico da Conyza spp. antes da semeadura da Glycine max, *Revista Brasileira de Desenvolvimento*, v. 7, p. 51187–51198, 2020. DOI: https://doi.org/10.34117/bjdv6n7-676

CASTILHO J.; FORTI, V.A.; MONQUERO P.A. Biology and Non-Chemical Management of *Spermacoce Verticillata* and *Spermacoce Densiflora*. *Renewable Agriculture and Food Systems,* v. 37, p. 103–12, 2022 DOI: https://doi.org/10.1017/S1742170521000375

CONAB – COMPANHIA NACIONAL DE ABASTECIMENTO. Acompanhamento da safra brasileira de grãos: safra 2024/25, 11º levantamento. Brasília, DF, 2025. Disponível em: https://www.conab.gov.br/info-agro/safras/graos/boletim-da-safra-de-graos. Acesso em: 01/jun. 2025.

DIESEL, F. et al. Tolerance to glyphosate in broadleaf buttonweed and White-eye biotypes. *Planta Daninha*, v.36, p.1-14, 2018. DOI: https://doi.org/10.1590/S0100-83582018360100137

EWRC - EUROPEAN WEED RESEARCH COUNCIL. Report of the 3rd, and 4th meetings of EWRC. Comitte of methods in Weed Research. *Weed Research,* v. 4, p. 88, 1964.

FADIN, D. A.; MONQUEIRO, P. A. Leaf characterization of Spermacoce verticillata at three stages of development. *Australian Journal of Crop Science*, v. 13, n. 5, p. 792-797, 2019. DOI: https://doi.org/10.21475/ajcs.19.13.05.p1663

FADIN, D. A.; TORNISIELO, V. L.; BARROSO, A. A. M.; RAMOS, S.; DOS REIS, F. C.; MONQUERO, P. A. Absorption and translocation of glyphosate in Spermacoce verticillata and alternative herbicide control. *Weed Research*, v. 58, n. 5, p. 389–396, 2018. DOI: https://doi.org/10.1111/wre.12329

FURTADO, J. A. L. et al. Uso de herbicidas residuais para o manejo de plantas daninhas tolerantes a glifosato no cerrado maranhense. *Revista Científica Multidisciplinar Núcleo do Conhecimento*, v. 2, p. 24-40, 2025. https://doi.org/10.32749/nucleodoconhecimento.com.br/agronomia/manejo-de-plantas

GALLON, M. et al. Chemical management of broadleaf buttonweed and Brazilian pusley in different application methods. *Planta Daninha*, v. 37, p. e019185625, 2019. DOI: https://doi.org/10.1590/S0100- 83582019370100098

Gomes dos Santos , A. L., Veiga, L. M. da, Santos, Z. O., Lança Rodrigues , J. G., & Codognoto, V. M. (2024). Importância das técnicas de inoculação e coinoculação na cultura da soja. *Scientific Electronic Archives*, *18*(1). https://doi.org/10.36560/18120252019

Gomes, S. A., Botelho, F. B. S., Arantes, S. A. C. M., & Santos, A. (2013). Effect of different doses of glyphosate in soybean. *Scientific Electronic Archives*, *3*, 24–28. https://doi.org/10.36560/30201337

GONESE, J. U.; WEBER, J. B. Herbicide rate recommendations: soil parameter equations vs. registered rate recommendations. *Weed Technology*, v. 12, n. 2, p. 235–242, 1998. DOI: https://doi.org/10.1017/S0890037X00043748

INMET- Instituto Nacional de Meteorologia. Precipitação pluviométrica em Mata-Roma (MA). Disponível em: https://portal.inmet.gov.br/. Acesso em: 28 de janeiro 2025.

KALSING, A. et al. Efeito de pulverizações sequenciais de flumioxazina e glufosinato sobre o controle de plantas daninhas tolerantes ou resistentes ao glifosato. *Ensaio e Ciência*, v. 29, n. 3, p. 655–669, 2025. DOI: https://doi.org/10.17921/1415-6938.2025v29n3p655-669

MOREIRA, K. L. et al. Aplicabilidade de métodos da agricultura de precisão no manejo integrado de vassourinha-de-botão (*Spermacoce verticillata*) e poia-branca (*Richardia brasiliensis*). *Caderno Pedagógico*, v. 21, p. e8404, 2024. DOI: https://doi.org/10.54033/cadpedv21n9-333

NEPOMUCENO, F. A. A. et al. O gênero Borreria (*Spermacoceae, Rubiaceae*) no estado do Ceará, Brasil. Rodriguésia**,** v. 69, n. 2, p. 715-731, 2018. DOI: https://doi.org/10.1590/2175-7860201869232

Panisson, A. C. ., Felicio, T. P., Sponchiado, J. C. ., Xavier, K. L. ., & Mantovani, A. (2022). Qualidade fisiológica e sanitária de sementes comerciais e salvas de soja (Glycine max.) produzidas na região do meio oeste de Santa Catarina. *Scientific Electronic Archives*, *15*(6). https://doi.org/10.36560/15620221545

Pereira, C. S., & Sampaio , P. do C. . . (2023). Diferentes temperaturas da água de irrigação na cultura da soja. *Scientific Electronic Archives*, *17*(1). https://doi.org/10.36560/17120241840

Pereira, C. S., Medeiros, A. L., Silva, A. A., Arantes, S. A. C. M., Coutinho, P. S., Fiorini, I. V. A., & Lange, A. (2018). Forms of nitrogen fertilization on soybean in the northern of Mato Grosso State, Brazil. *Scientific Electronic Archives*, *11*(5), 60–66. https://doi.org/10.36560/1152018622

Pereira, C. S., Schineider , Y. C. ., Fiorini , I. V. A., Pereira, H. D., Silva , A. A. da ., & Lange, A. (2021). Produtividade com sementes pré-inoculadas de soja em períodos antes da semeadura . *Scientific Electronic Archives*, *14*(11). https://doi.org/10.36560/141120211428

PEREIRA, C. S.; KERBER, J. C.; FIORINI, I. V. A. Controle de plantas daninhas na cultura da soja com aplicação de glifosato por contato com rolo de polyester. *Revista Brasileira de Herbicidas*, v.18, n. 4. 2019. DOI: https://doi.org/10.7824/rbh.v18i4.667

PONTE, I. S. et al. Aerial survey and glyphosate-resistant weeds control before soybean seeding. *Australian Journal of Crop Science*, v.18 n.1, 29–36. 2024. DOI: https://doi.org/10.21475/ajcs.24.18.01.p4019

Santos Neto, J. V., Lima, L. C., Cardoso, A. F., Lana, R. M. Q., & Torres, J. L. R. (2018). Micronutrients in soybean culture in direct plantaining systems in closed soils. *Scientific Electronic Archives*, *11*(5), 33–39. https://doi.org/10.36560/1152018551

SANTOS, H. G. et al. Sistema Brasileiro de Classificação de Solos. 5. ed., rev. e ampl., Brasília, DF: Embrapa, 2018

SANTOS, M. G. M. et al. Alternatives for pre-harvest soybean desiccation and buttonweed (*Spermacoce verticillata L.*) control. *Ensaios e ciência: ciências biológicas, agrárias e da saúde*, v. 29, p. 53-65, 2025. DOI: https://doi.org/10.17921/1415-6938.2025v29n1p53-65

Serafim, M. N., Araújo, R. M. R. de, Abdala, A. G., Santos, B. V. dos, Conceição, E. J. de C. da, Silva , F. P. da, … Berti, M. P. da S. (2026). Dinâmica do cobalto no sistema solo-planta e sua participação no metabolismo e nutrição de plantas: uma revisão. *Scientific Electronic Archives*, *19*(4), 1–9. https://doi.org/10.36560/19420262209

Shiomi, H. F., Ferreira, M. V. R., & Melo, I. S. (2017). Bioprospecting bacterial strains for biological control of white mold on soybean. *Scientific Electronic Archives*, *10*(2), 56–63. https://doi.org/10.36560/1022017432

SILVA, L. R. D. et al. Glyphosate-resistant weeds control with double-shooting in soybean pre-planting. *Ensaios e ciência: ciências biológicas, agrárias e da saúde*, v. 29, p. 655-669, 2025. DOI: https://doi.org/10.17921/1415-6938.2025v29n3p655-669

SILVA, M. M. et al. Pre-emergence herbicides effects in no-till soybean system with Panicum maximum? BRS Taman. *Australian Journal of Crop Science*, v. 18, p. 21-28, 2024. DOI: https://doi.org/10.21475/ajcs.24.18.01.p4018

Silva, V. L., Rodrigues, L. M., Lima, V. M. M., & Ferreira, J. O. (2018). Herbicides ACCase interaction and ALS with glyphosate on corn tiguera control RR. *Scientific Electronic Archives*, *11*(4), 24–30. https://doi.org/10.36560/1142018524

Silva-Abud, L. L., Ferrari, G. S., Lima, V. M. M. ., & Stival, M. M. . (2021). Coinoculação de Azospirillum brasilense e Bradyrhizobium japonicum no desenvolvimento da soja. *Scientific Electronic Archives*, *14*(7), 25–32. https://doi.org/10.36560/14720211328

SOCIEDADE BRASILEIRA DA CIÊNCIA DAS PLANTAS DANINHAS - SBCPD. Procedimentos para instalação, avaliação e análise de experimentos com herbicidas. Londrina, PR, 1995. 42 p.