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Mixtures of herbicides for the control of multiple resistant *Conyza sumatrensis* in soybean pre-sowing burndown

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ABSTRACT: The objective of this study was to evaluate the effectiveness of synthetic auxins in the control of *Conyza sumatrensis* in mixtures for use in the first application, and the effectiveness of burndown herbicides alone or in mixtures for use in the second application, in soybean pre-sowing. Experiment 1 consisted of auxin herbicides (fluroxypyr or dicamba) in mixtures with herbicides (glyphosate, glufosinate, saflufenacil, carfentrazone, and chlorimuron) used for the first application in pre-sowing. Experiment 2 consisted of burndown herbicides (diquat, glufosinate, glyphosate, chlorimuron, saflufenacil, and carfentrazone), alone or at mixtures, used for sequential application in pre-sowing. For the first application, the effectiveness of glyphosate + dicamba or fluroxypyr was low and must be complemented by the addition of a PPO-inhibiting herbicide, mainly saflufenacil. The mixture of glufosinate, instead of glyphosate, with synthetic auxin was more effective, even increasing with the addition of saflufenacil. For the second application, with burndown herbicides, glufosinate was superior and effective when mixed with saflufenacil. For the first application in soybean pre-sowing, glyphosate or glufosinate + synthetic auxin + saflufenacil are effective for the control of *C. sumatrensis*. For the second application, glufosinate at mixtures is effective in controlling *C. sumatrensis*.

Key words: Sumatran fleabane; dicamba; fluroxypyr; glufosinate; saflufenacil

Misturas de herbicidas para o controle de *Conyza sumatrensis* com resistência múltipla na dessecação pré-semeadura da soja

RESUMO: O objetivo deste estudo foi avaliar a eficácia de auxinas sintéticas no controle de *Conyza sumatrensis* em misturas para uso na primeira aplicação, e a eficácia de herbicidas para dessecação isolados ou em misturas para uso na segunda aplicação, em pré-semeadura da soja. O Experimento 1 consistiu-se em herbicidas auxínicos (fluroxipir ou dicamba) em mistura com herbicidas (glifosato, glufosinato, saflufenacil, carfentrazona e clorimurom) utilizados na primeira aplicação em pré-semeadura. O Experimento 2 consistiu-se em herbicidas para dessecação (diquate, glufosinato, glifosato, clorimurom, saflufenacil, carfentrazona), isolados ou em misturas, na aplicação sequencial em pré-semeadura. Para a primeira aplicação, a eficácia de glifosato + dicamba ou fluroxipir foi baixa e deve ser complementada com a adição de um herbicida inibidor da PPO, principalmente saflufenacil. A mistura de glufosinato, em vez de glifosato, com auxina sintética foi mais eficaz, com incremento devido a adição de saflufenacil. Para a segunda aplicação, com herbicidas para a dessecação, o glufosinato foi superior e eficaz em mistura com saflufenacil. Para primeira aplicação na pré-semeadura da soja, glifosato ou glufosinato + auxina sintética + saflufenacil são eficazes para o controle de *C. sumatrensis*. Para a segunda aplicação, o glufosinato em misturas é eficaz no controle de *C. sumatrensis*.

Palavras-chave: buva; dicamba; fluroxipir; glufosinato; saflufenacil

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Introduction

Sumatran fleabane (*Conyza sumatrensis* [Retz.] E.Walker, sin.: *Erigeron sumatrensis* Retz.) is one of the main weeds in soybean crops. It belongs to the family Asteraceae, with characteristics of annuality, herbaceous, erect and reproduction by seeds. Furthermore, it can produce hundreds of thousands of viable seeds, which aids in their dispersal, as they are easily carried by the wind and in animal fur. Damage caused by *C. sumatrensis* to soybean crops is related to reduced productivity and reduced final quality of the product (Bajwa et al., 2016).

Another aspect that increases the problem of this species are cases of herbicide resistance, which makes it difficult to manage the weed and can increase production costs (Baccin et al., 2022). In Brazil, there are cases of *C. sumatrensis* with multiple resistance to chlorimuron and glyphosate, simple resistance to paraquat, in addition to cases of single or multiple resistance to these and other herbicides (photosystem II inhibitors and synthetic auxins) (Pinho et al., 2019; Albrecht et al., 2020a; Queiroz et al., 2020; Lorenzetti et al., 2024). Also in Paraguay, a country bordering Brazil, there is a report of a biotype with triple resistance to paraquat, chlorimuron and glyphosate (Albrecht et al., 2020b).

The main control method for *C. sumatrensis* is chemical, which can be performed at different times. Herbicides can be applied in the pre-sowing burndown of soybeans using pre- or post-emergence herbicides, and after soybean sowing with herbicides that are selective and can be used after crop emergence (Barbosa et al., 2023). Pre-sowing burndown is recommended, as it is when there is the greatest emergence flow of *C. sumatrensis*, the plant is still at the juvenile stage, which facilitates its control, avoiding regrowth and seed production.

In areas with high infestations and/or resistance to herbicides, two or more applications in the pre-sowing burndown of soybeans are required for effective control of *C. sumatrensis*. In the first application, mixtures of glyphosate with synthetic auxins, such as dicamba (Soltani et al., 2022), 2,4-D (Silva et al., 2023), triclopyr, halauxifen (Cantu et al., 2021) or fluroxypyr (Quinn et al., 2020), are commonly used. In the second application, burndown herbicides, such as diquat (Albrecht et al., 2022a) or glufosinate (Dilliott et al., 2022) are used.

In the first, sequential or single application, in soybean pre-sowing, herbicides that inhibit acetolactate synthase (ALS), protoporphyrinogen oxidase (PPO), or other mechanisms of action can also be used (Albrecht et al., 2021; Westerveld et al., 2021) with the purpose of increasing the burndown effect in post-emergence of weeds and/or the residual effect in pre-emergence, depending on the herbicide.

In this context, it is important to characterize herbicide options for the control of *C. sumatrensis* in soybean pre-sowing burndown, for the first and second application, in a setting of plants with multiple resistance to herbicides. Thus, the objective was to evaluate the effectiveness of synthetic auxins in the control of *C. sumatrensis* in mixtures for use in the first application, and the effectiveness of burndown herbicides alone or in mixtures for use in the second application, in soybean pre-sowing.

Materials and Methods

Two experiments were carried out in areas infested with *C. sumatrensis* in the state of Paraná, Brazil, in the off-season in August and September (after the off-season corn harvest, prior to soybean sowing). Experiment 1 consisted of auxin herbicides, alone or in mixtures, normally used for the first pre-sowing application in soybeans (Table 1), carried out in two locations in the municipality of Nova Santa Rosa (trial A: 24° 24’ 52.535” S, 53° 55’ 33.161” W; trial B: 24° 24’ 10.022” S, 53° 57’ 31.99” W). Experiment 2 consisted of burndown herbicides normally used for sequential application in soybean pre-sowing (Table 2), conducted in two locations (trial A: 24° 18’ 9.508” S, 53° 55’ 26.897” W - Palotina; location B: 24° 24’ 10.022” S, 53° 57’ 31.99” W - Nova Santa Rosa).

According to the Koppen-Geiger classification, the climate of the region is classified as mesothermal humid subtropical (Cfa). The meteorological data collected during the experiments are illustrated in Figure 1. The soil in the experimental areas was classified as eutroferric clayey Red Latosol (Nova Santa Rosa: 65.5% clay, 24.5% silt, 10% sand, 2.5% organic matter; Palotina: 63.2% clay, 25.3% silt, 11.5% sand, 2.8% organic matter).

A randomized block design with four replications was adopted. The experimental units were composed of 3 × 5

Table 1. Auxinic herbicides at mixtures for *C. sumatrensis* control, for 1st application before soybean sowing. Experiment 1, 2020.

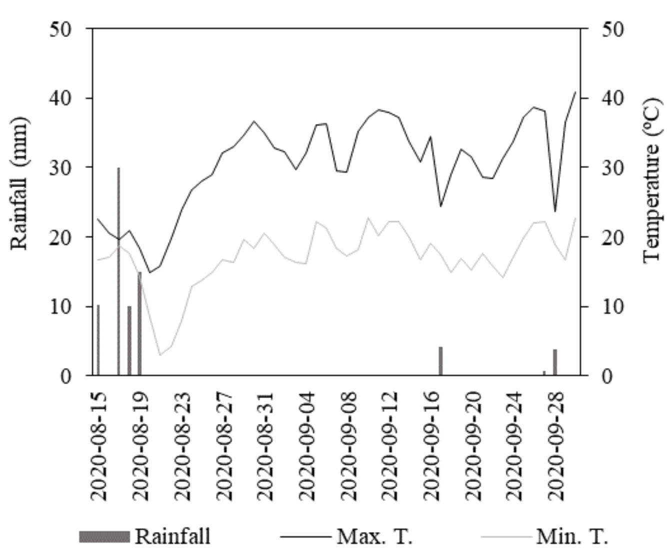
Treatment[1]	Rate[2] (g ae ha^{-1})
Untreated control	-
Glyphosate + fluroxypyr	1,250 + 200
Glyphosate + dicamba	1,250 + 288
Glufosinate + fluroxypyr	400 + 200
Glufosinate + dicamba	400 + 288
Glyphosate + fluroxypyr + saflufenacil	1,250 + 200 + 49
Glyphosate + fluroxypyr + carfentrazone	1,250 + 200 + 30
Glyphosate + fluroxypyr + chlorimuron + saflufenacil	1,250 + 200 + 20 + 49
Glyphosate + dicamba + saflufenacil	1,250 + 288 + 49
Glyphosate + dicamba + carfentrazone	1,250 + 288 + 30
Glyphosate + dicamba + chlorimuron + saflufenacil	1,250 + 288 + 20 + 49
Glufosinate + fluroxypyr + saflufenacil	200 + 400 + 49
Glufosinate + dicamba + saflufenacil	288 + 400 + 49
Glufosinate + fluroxypyr + carfentrazone	200 + 400 + 30
Glufosinate + dicamba + carfentrazone	288 + 400 + 30

[1] Commercial products: Zapp® QI 620 (glyphosate), Starane® 200 (fluroxypyr), Atectra® (dicamba), Finale® (glufosinate), Heat® (saflufenacil), Aurora® 400 EC (carfentrazone), Classic® (chlorimuron). [2] Rates at g ai ha^{-1} for glufosinate, carfentrazone, and chlorimuron.

Table 2. Burndown herbicides alone or in mixtures for *C. sumatrensis* control, for sequential application before soybean sowing. Experiment 2, 2020.

Treatment[1]	Rate[2] (g ai ha^{-1})
Untreated control	-
Diquat	400
Glufosinate	400
Glufosinate	600
Glufosinate + chlorimuron	400 + 20
Glyphosate + saflufenacil	1,250 + 49
Glyphosate + carfentrazone	1,250 + 30
Glufosinate + saflufenacil	400 + 35
Glufosinate + saflufenacil	400 + 49
Glufosinate + carfentrazone	400 + 20
Glufosinate + carfentrazone	400 + 30
Glyphosate + carfentrazone + saflufenacil	1,250 + 20 + 35
Glufosinate + carfentrazone + saflufenacil	400 + 20 + 35
Glufosinate + carfentrazone + chlorimuron	400 + 30 + 20
Glufosinate + saflufenacil + chlorimuron	400 + 49 + 20

[1] Commercial products: Reglone® (diquat), Finale® (glufosinate), Zapp® QI 620 (glyphosate), Classic® (chlorimuron); Heat® (saflufenacil), Aurora® 400 EC (carfentrazone). [2] Rates at g ae ha^{-1} for glyphosate.



Source: Weather station located in Palotina, PR (24° 10′ 44.5″ S, 53° 50′ 16.4″ W).

Figure 1. Rainfall, maximum and minimum temperature for the region where the experiments are conducted. PR, Brazil, 2021.

m plots. Upon application of treatments for experiment 1, trial A had infestation of 16.7 *C. sumatrensis* plants m^{-2}, and trial B, 25.4 plants m^{-2}. In experiment 2, trial A was infested with 18.3 plants m^{-2}, and trial B, with 27.5 plants m^{-2}. At all trials, there was a high incidence of *C. sumatrensis* plants with multiple resistance to glyphosate, paraquat/diquat, 2,4-D and moderate incidence of resistance to chlorimuron.

The application in experiment 1, trial A, was carried out on August 27, 2020, under temperature (T) of 22.9 °C, relative air humidity (RH) of 53% and wind of 6 km h^{-1}. At trial B, on August 29, 2020, under T of 23.1 °C, 50% RH and 5 km h^{-1} wind. The application in experiment 2, for trial A, was carried out on August 27, 2020, under T of 29.6 °C, 50% RH and 4 km h^{-1} wind. At trial B, on August 29, 2020, under T 23.4 °C, 51% RH and 5 km h^{-1} wind.

The application was carried out in post-emergence of *C. sumatrensis* plants with up to 14 leaves (2.5 and 17.5 cm in height). A CO_2 pressurized backpack sprayer was used, with a pressure of 2 kgf cm^{-2}, equipped with a bar with 6 fan jet nozzles (AIXR 110.015), with spacing of 0.5 m between nozzles. A distance of 0.5 m was adopted between the nozzles and the plants, at a speed of 1 m s^{-1}, which provided an application volume of 150 L ha^{-1}.

The control of *C. sumatrensis* was evaluated at 7, 14, 21, and 28 days after application (DAA). For evaluation, a visual scale from 0 (no symptoms) to 100% (plant death) was used (Velini et al., 1995). Data were tested by analysis of variance (ANOVA) using the F-test ($p \leq 0.05$). The means of the treatments were subjected to the Scott-Knott test, at the 5% probability level. The analyses were run in the software Sisvar 5.6.

Results and Discussion

For the control of *C. sumatrensis* in experiment 1 (trial A), at 7 DAA, the treatments glyphosate + fluroxypyr + chlorimuron + saflufenacil, glyphosate + dicamba + chlorimuron + saflufenacil, fluroxypyr + glufosinate + saflufenacil, dicamba + glufosinate + saflufenacil, fluroxypyr + glufosinate + carfentrazone and dicamba + glufosinate + carfentrazone resulted in excellent control (> 90%). The other treatments showed efficacy between 60.8 and 89% (Table 3).

At 14 DAA, except for glyphosate + fluroxypyr, glyphosate + dicamba, glyphosate + fluroxypyr + carfentrazone and glyphosate + dicamba + carfentrazone, all showed control scores > 90%. At 21 DAA, the most effective treatment was the fluroxypyr + glufosinate + saflufenacil mixture, with 98% control, while the lowest control score was 61.3% for the glyphosate + fluroxypyr mixture. The most effective treatment at 28 DAA was glyphosate + dicamba + chlorimuron + saflufenacil, with 98.5% control, followed by fluroxypyr + glufosinate + saflufenacil (98%), dicamba + glufosinate + saflufenacil (96.5%), glyphosate + fluroxypyr + chlorimuron + saflufenacil (96%), glyphosate + dicamba + saflufenacil (91%) and glyphosate + fluroxypyr + saflufenacil (90.8%). The other treatments showed efficacy < 90% (Table 3).

Still in experiment 1, trial B, at 7 DAA, none of the treatments showed control >90%, and only dicamba + glufosinate + saflufenacil (87.8%), fluroxypyr + glufosinate + saflufenacil (86.8%), glyphosate + fluroxypyr + chlorimuron + saflufenacil (81.8%) and fluroxypyr + glufosinate + carfentrazone (80%) showed efficacy between 80 and 90%, the others had lower scores (Table 4).

Only dicamba + glufosinate + saflufenacil showed excellent control, with 93.8% at 14 DAA. The other treatments

Table 3. *Conyza sumatrensis* control at 7, 14, 21, and 28 days after application (DAA) of auxinic herbicides at mixtures. Experiment 1, trial A, 2020.

Treatment	Rate[1] (g ae ha^{-1})	7 DAA	14 DAA	21 DAA	28 DAA
		(%)			
Untreated control	-	0.0 e	0.0 d	0.0 e	0.0 f
Glyphosate (gly) + fluroxypyr	1,250 + 200	60.8 d	63.8 c	61.3 d	52.5 e
Gly + dicamba	1,250 + 288	69.5 c	77.5 b	71.8 c	70.8 c
Glufosinate (glu) + fluroxypyr	400 + 200	87.5 b	92.3 a	86.3 b	85.8 b
Glu + dicamba	400 + 288	86.3 b	93.8 a	90.0 b	88.3 b
Gly + fluroxypyr + saflufenacil	1,250 + 200 + 49	81.8 b	93.5 a	92.8 a	90.8 b
Gly + fluroxypyr + carfentrazone	1,250 + 200 + 30	70.3 c	78.0 b	65.0 d	61.8 d
Gly + fluroxypyr + chlorimuron + saflufenacil	1,250 + 200 + 20 + 49	91.5 a	95.8 a	96.3 a	96.0 a
Gly + dicamba + saflufenacil	1,250 + 288 + 49	89.0 b	94.5 a	93.0 a	91.0 b
Gly + dicamba + carfentrazone	1,250 + 288 + 30	69.3 c	75.0 b	71.8 c	68.8 c
Gly + dicamba + chlorimuron + saflufenacil	1,250 + 288 + 20 + 49	91.8 a	96.0 a	97.3 a	98.5 a
Glu + fluroxypyr + saflufenacil	200 + 400 + 49	95.5 a	98.0 a	98.0 a	98.0 a
Glu + dicamba + saflufenacil	288 + 400 + 49	96.3 a	96.5 a	96.0 a	96.5 a
Glu + fluroxypyr + carfentrazone	200 + 400 + 30	90.0 a	96.5 a	89.5 b	86.5 b
Glu + dicamba + carfentrazone	288 + 400 + 30	93.0 a	96.0 a	87.0 b	85.0 b
CV (%)		5.7	4.5	5.4	5.5

[1] Rates at g ai ha^{-1} for glufosinate, carfentrazone, and chlorimuron.
Means with same letter do not differ by each other by Scott and Knott test ($p \geq 0.05$).

Table 4. *Conyza sumatrensis* control at 7, 14, 21, and 28 days after application (DAA) of auxinic herbicides at mixtures. Experiment 1, trial B, 2020.

Treatment	Rate[1] (g ae ha^{-1})	7 DAA	14 DAA	21 DAA	28 DAA
		(%)			
Untreated control	-	0.0 e	0.0 f	0.0 f	0.0 d
Glyphosate (gly) + fluroxypyr	1,250 + 200	51.3 d	57.5 e	55.0 e	46.3 c
Gly + dicamba	1,250 + 288	56.5 d	66.3 d	66.3 d	65.0 b
Glufosinate (glu) + fluroxypyr	400 + 200	74.5 c	82.8 b	74.5 c	68.0 b
Glu + dicamba	400 + 288	71.8 c	75.0 c	72.0 c	68.3 b
Gly + fluroxypyr + saflufenacil	1,250 + 200 + 49	75.5 c	81.8 b	78.8 b	69.5 b
Gly + fluroxypyr + carfentrazone	1,250 + 200 + 30	56.3 d	64.3 d	56.8 e	49.5 c
Gly + fluroxypyr + chlorimuron + saflufenacil	1,250 + 200 + 20 + 49	81.8 b	89.5 a	88.8 a	84.5 a
Gly + dicamba + saflufenacil	1,250 + 288 + 49	74.8 c	85.5 b	83.5 b	81.3 a
Gly + dicamba + carfentrazone	1,250 + 288 + 30	54.3 d	69.8 c	66.8 d	63.8 b
Gly + dicamba + chlorimuron + saflufenacil	1,250 + 288 + 20 + 49	73.3 c	80.5 b	82.5 b	82.5 a
Glu + fluroxypyr + saflufenacil	200 + 400 + 49	86.8 a	74.8 c	72.3 c	70.0 b
Glu + dicamba + saflufenacil	288 + 400 + 49	87.8 a	93.8 a	92.5 a	88.8 a
Glu + fluroxypyr + carfentrazone	200 + 400 + 30	80.0 b	76.3 c	73.0 c	67.0 b
Glu + dicamba + carfentrazone	288 + 400 + 30	79.5 c	89.0 a	86.8 a	80.8 a
CV (%)		7.8	6.4	6.3	9.1

[1] Rates at g ai ha^{-1} for glufosinate, carfentrazone, and chlorimuron.
Means with same letter do not differ by each other by Scott and Knott test ($p \geq 0.05$).

showed efficacy between 57.5 and 89.5%. At 21 DAA, again dicamba + glufosinate + saflufenacil was the most effective with 92.5% control. The treatments glyphosate + fluroxypyr + chlorimuron + saflufenacil, dicamba + glufosinate + carfentrazone, glyphosate + dicamba saflufenacil and glyphosate + dicamba + chlorimuron + saflufenacil showed efficacy of 80%, and the other treatments had control of less than 80% (Table 4).

No treatment showed control above 90% at 28 DAA. The most effective treatment was dicamba + glufosinate + saflufenacil, with 88.8% control, followed by glyphosate + fluroxypyr + chlorimuron + saflufenacil (84.5%), glyphosate + dicamba + chlorimuron + saflufenacil (82.5%), glyphosate + dicamba + saflufenacil (81.3%) and dicamba + glufosinate + carfentrazone (80.8%). The other treatments showed efficacy < 70% (Table 4).

Soares et al. (2012) observed that the herbicide dicamba, applied alone or combined with glyphosate, showed excellent control of *C. bonariensis*; however, in the present study, the mixture of herbicides did not demonstrate high efficacy. Nevertheless, with the addition of saflufenacil, the mixture of dicamba and glyphosate can be a control alternative with excellent results.

Glyphosate is widely used to control *Conyza* spp. especially in the first application in soybean pre-sowing, in mixtures with synthetic auxins (Soltani et al., 2022). The results of this study indicate that the efficacy is low and must be complemented with a PPO-inhibiting herbicide, mainly saflufenacil. The application of glyphosate is effective for controlling susceptible *Conyza* spp. at an early stage of development, however, the same does not occur for chlorimuron, and for glyphosate in resistant plants (Kaspary et al., 2021). However, these herbicides can be applied in mixtures and their different mechanisms of action can complement each other and improve weed control, as occurred in the mixture glyphosate + fluroxypyr + chlorimuron + saflufenacil.

On the other hand, in general, the mixture of glufosinate, instead of glyphosate, with synthetic auxin was more effective, even with an increase with the addition of saflufenacil. The application of glufosinate + synthetic auxin (mainly dicamba) + PPO inhibitor (mainly saflufenacil) was effective in controlling *C. sumatrensis* in this study, representing a viable alternative for pre-sowing burndown of soybeans with a single application. The mixture of glufosinate with PPO inhibitors is reported to be effective in controlling broadleaf weeds, even with a synergistic effect in some cases (Jhala et al., 2013; Takano et al., 2020), the results of this study are promising for the triple mixture with the addition of dicamba or fluroxypyr. Other studies have also observed the effectiveness of dicamba (Cantu et al., 2021; Soltani et al., 2022) or fluroxypyr (Quinn et al., 2020), in different chemical management programs. It should be noted that between the application of dicamba and sowing of soybeans (non-tolerant), an interval of 30 or 45 days is required, depending on the rate. While for fluroxypyr there is no restriction on the interval between application and sowing (MAPA, 2024).

For experiment 2, trial A, at 7 DAA, treatments with glufosinate + saflufenacil (both doses) were the most effective. At 14 DAA, the same treatments showed the best control results, in addition to treatments with glufosinate + carfentrazone + chlorimuron, glufosinate + carfentrazone (at the highest dose), glufosinate (at the highest dose) and glufosinate + chlorimuron. At 21 and 28 DAA, there was an increase in control effectiveness, except for diquat, glyphosate + saflufenacil, glyphosate + carfentrazone, glyphosate + carfentrazone + saflufenacil (Table 5).

In experiment 2, trial B, at 7 DAA, none of the treatments showed control > 90%. The most effective treatment (86.5%) was glufosinate + saflufenacil + chlorimuron, followed by glufosinate + saflufenacil (at the highest dose) (86%), glufosinate + carfentrazone + saflufenacil (84.5%), glufosinate + saflufenacil (the lowest dose) and glufosinate + carfentrazone (at the highest dose), both with 83.8% control. At 14 DAA, glufosinate + saflufenacil + carfentrazone resulted in 91.5% control and glufosinate + saflufenacil, 90%, while the others showed control < 90% (Table 6).

At 21 DAA, glufosinate + saflufenacil + chlorimuron and glufosinate + saflufenacil (at the highest dose) were the most effective, with 91.8 and 90.5% control, respectively. Glufosinate + saflufenacil (at the highest dose), glufosinate + carfentrazone + saflufenacil and glufosinate + carfentrazone + chlorimuron showed 89.5, 83.3, and 83% control; the others had efficacy < 80%. At 28 DAA, glufosinate + saflufenacil at (highest dose) was the most effective (95.5%), followed by glufosinate + saflufenacil + chlorimuron (94.5%) and glufosinate + saflufenacil at the lowest dose (94.3%). Glufosinate + carfentrazone + saflufenacil and glufosinate + carfentrazone + chlorimuron presented control of 83 and 81.8%, respectively (Table 6).

The least effective treatment was diquat, which can be explained by the resistance of *C. sumatrensis* to paraquat (Lorenzetti et al., 2024), an herbicide with the mechanism of action of photosystem I inhibitors, the same mechanism in diquat. Moreover, the population is also resistant to glyphosate, so in some cases, even when mixed with other herbicides, such as chlorimuron and carfentrazone, control was ineffective.

Table 5. *Conyza sumatrensis* control at 7, 14, 21, and 28 days after application (DAA) of burndown herbicides, alone or in mixtures. Experiment 2, trial A, 2020.

Treatment	Rate[1] (g ai ha^{-1})	7 DAA	14 DAA	21 DAA	28 DAA
		(%)			
Untreated control	-	0.0 f	0.0 f	0.0 f	0.0 g
Diquat	400	11.8 e	27.5 e	22.8 e	15.8 f
Glufosinate (glu)	400	58.5 c	87.8 b	85.5 b	79.5 c
Glu	600	75.0 b	93.4 a	90.3 b	86.5 b
Glu + chlorimuron	400 + 20	69.5 b	93.8 a	93.0 a	91.3 a
Glyphosate (gly) + saflufenacil	1,250 + 49	49.0 d	73.8 c	65.3 c	46.3 e
Gly + carfentrazone	1,250 + 30	17.0 e	48.8 d	46.0 d	41.0 e
Glu + saflufenacil	400 + 35	87.0 a	94.3 a	93.3 a	86.8 b
Glu + saflufenacil	400 + 49	86.8 a	94.5 a	96.8 a	97.3 a
Glu + carfentrazone	400 + 20	70.8 b	87.5 b	85.0 b	80.5 c
Glu + carfentrazone	400 + 30	69.3 b	91.0 b	86.5 b	80.8 c
Gly + carfentrazone + saflufenacil	1,250 + 20 + 35	44.8 d	72.5 c	62.5 c	58.3 d
Glu + carfentrazone + saflufenacil	400 + 20 + 35	76.3 b	88.3 b	86.5 b	82.0 c
Glu + carfentrazone + chlorimuron	400 + 30 + 20	73.0 b	94.3 a	96.0 a	92.8 a
Glu + saflufenacil + chlorimuron	400 + 49 + 20	84.5 a	94.5 a	96.3 a	96.5 a
CV (%)		8.3	4.7	5.1	6.2

[1] Rates at g ae ha^{-1} for glyphosate.
Means with same letter do not differ by each other by Scott and Knott test ($p \geq 0.05$).

Table 6. *Conyza sumatrensis* control at 7, 14, 21, and 28 days after application (DAA) of burndown herbicides, alone or in mixtures. Experiment 2, trial B, 2020.

Treatment	Rate[1] (g ai ha^{-1})	7 DAA	14 DAA	21 DAA	28 DAA
		(%)			
Untreated control	-	0.0 f	0.0 f	0.0 h	0.0 h
Diquat	400	24.3 e	19.3 e	14.8 g	13.5 g
Glufosinate (glu)	400	61.3 d	66.3 d	62.0 d	60.0 d
Glu	600	72.5 b	83.0 b	77.8 c	76.3 c
Glu + chlorimuron	400 + 20	68.3 c	74.3 c	78.3 c	91.8 a
Glyphosate (gly) + saflufenacil	1,250 + 49	60.5 d	63.0 d	56.5 e	51.8 e
Gly + carfentrazone	1,250 + 30	23.8 e	22.5 e	21.3 f	21.3 f
Glu + saflufenacil	400 + 35	83.8 a	90.5 a	90.5 a	94.3 a
Glu + saflufenacil	400 + 49	86.0 a	89.5 a	89.5 a	95.5 a
Glu + carfentrazone	400 + 20	75.0 b	81.3 b	76.5 c	75.3 c
Glu + carfentrazone	400 + 30	83.8 b	80.5 b	77.5 c	74.5 c
Gly + carfentrazone + saflufenacil	1,250 + 20 + 35	62.0 d	62.0 d	53.8 e	52.5 e
Glu + carfentrazone + saflufenacil	400 + 20 + 35	84.5 a	86.8 a	83.3 b	83.0 b
Glu + carfentrazone + chlorimuron	400 + 30 + 20	76.3 b	84.5 b	83.0 b	81.8 b
Glu + saflufenacil + chlorimuron	400 + 49 + 20	86.5 a	91.5 a	91.8 a	94.5 a
CV (%)		8.3	6.7	5.5	5.6

[1] Rates at g ae ha^{-1} for glyphosate.
Means with same letter do not differ by each other by Scott and Knott test ($p \geq 0.05$).

Although Tahmasebi et al. (2018) observed excellent results with the application of glufosinate alone, the results of the present study showed no effective control of *C. sumatrensis* when applied alone. This can occur due to several factors, such as the stage at which the plants were at the time of application and the high level of infestation.

On the other hand, when glufosinate is used in a mixture, such as saflufenacil, there is a significant improvement in control levels, because the action of the two herbicides can complement each other. As reported by Jhala et al. (2013), in different weed species, the mixture of saflufenacil and glufosinate, when applied together, was more effective in controlling and reducing the density of weeds than when applied in isolation. The mixture of saflufenacil with glyphosate, however, did not achieve the same control response, obtaining lower averages, unlike what was observed in another study, in which the mixture of the two herbicides was efficient and better than when applied in isolation for the control of *Conyza bonariensis* (Dalazen et al., 2015).

Saflufenacil can be effective when applied in early stages of *Conyza* spp., however, when at more advanced stages, mixing with glyphosate, for example, or sequential applications is recommended (Cantu et al., 2021). The mixture of glyphosate with carfentrazone also showed low efficacy, different from what was observed by Tahmasebi et al. (2018).

For the application of desiccant herbicides, the isolated application of the herbicide is not effective. However, when considering a management with of two applications it can be interesting. In this context, glufosinate stands out again, which, as already mentioned, has increased effectiveness when mixed with saflufenacil. In summary of this set of experiments, the choice of how many herbicides and applications must consider several factors. The application of glufosinate or glyphosate + synthetic auxin + PPO inhibitor (mainly saflufenacil) can be recommended. The single application of these herbicides can be carried out, but according to the literature in situations of high infestation and advanced stages of the plants, sequential application is recommended.

Sequential application in soybean pre-sowing was widely used with paraquat. However, it was no longer effective due to the resistance of *C. sumatrensis* to this herbicide (Pinho et al., 2019; Lorenzetti et al., 2024). In the present study, even diquat was not effective, probably related to this mechanism. In addition, paraquat was banned in Brazil in 2021, and therefore it is necessary to investigate alternatives to this herbicide (Albrecht et al., 2022b). Therefore, the present study points to glufosinate as a substitute for paraquat in pre-sowing burndown to control *C. sumatrensis*, with increased efficacy in mixtures with PPO-inhibiting herbicides.

In case two applications are necessary in soybean pre-sowing, the results indicate glyphosate or glufosinate + synthetic auxin + saflufenacil, in which saflufenacil is more relevant if glyphosate is chosen, in the first application (experiment 1). While for the second application (experiment 2), the results indicate glufosinate, isolated or mixed with saflufenacil or carfentrazone. This study provides important information about herbicide options for the management of *C. sumatrensis*, especially for populations with multiple resistance.

Conclusions

For the first application in soybean pre-sowing, glyphosate or glufosinate + synthetic auxin + saflufenacil, in which saflufenacil shows greater relevance if glyphosate is chosen, are effective for controlling *C. sumatrensis*.

For the second application, glufosinate at mixtures is effective alternative to control *C. sumatrensis*.

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Compliance with Ethical Standards

Author contributions: Conceptualization: MC, AJPA, LPA; Data curation: MC, LPA, AJPA, AFMS; Formal analysis: MC, WFL, AJPA; Investigation: MC, AJPA, LPA, WFL, FGCG; Project Administration: AJPA, MC; Resources: AJPA, AFMS, LPA; Supervision: AJPA, LPA; Validation: AJPA, LPA; Visualization: AJPA, LPA, MC; Writing–original draft: AFMS, MC; Writing–review & editing: MC, AJPA, LPA, AFMS, WFL, FGCG.

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