Sequential application of herbicide options for controlling *Conyza sumatrensis* in soybean pre-sowing

Aplicación secuencial de opciones de herbicidas para el control de *Conyza sumatrensis* en presiembra de soja

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Abstract

The aim of this study was to evaluate the efficacy of sequentially applied herbicides to control *Conyza sumatrensis*, one of the most widely distributed weeds worldwide, in soybean pre-sowing burndown. The study was conducted under field conditions in the state of Paraná, Brazil, at 2018-2019 growing season. The experiment consisted of a randomized block design with four replicates, with 12 treatments consisting of different herbicide mixtures applied before sowing. Control of *C. sumatrensis*, injury to soybean plants, and variables related to agronomic performance were evaluated. The control levels were high for all treatments, except for the one that was free of saflufenacil in either of the two applications. These results highlight the importance of saflufenacil in the control of *C. sumatrensis* and show promise for the use of saflufenacil/imazethapyr when considering the system and other weeds. All studied treatments were selective to soybean, which showed higher injury values in the presence of diclosulam; however, this did not compromise the agronomic performance of soybean.

Keywords
ALS inhibitors • *Glycine max* • PROTOX inhibitors • sumatran fleabane • weeds

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Resumen

El objetivo de este estudio fue evaluar la eficacia de los herbicidas aplicados secuencialmente para controlar *Conyza sumatrensis*, una de las malezas más ampliamente distribuidas en todo el mundo, en la pre siembra de soja. El estudio se realizó en condiciones de campo en el estado de Paraná, Brasil, en la campaña 2018-2019. El experimento consistió en un diseño de bloques al azar con cuatro repeticiones, con 12 tratamientos compuestos por diferentes mezclas de herbicidas aplicados antes de la siembra. Se evaluó el control de *C. sumatrensis*, daño a plantas de soya y variables relacionadas con el comportamiento agronómico. Los niveles de control fueron altos para todos los tratamientos, excepto para el que estaba libre de saflufenacil en cualquiera de las dos aplicaciones. Estos resultados resaltan la importancia de *saflufenacil* en el control de *C. sumatrensis* y son prometedores para el uso de *saflufenacil/imazethapyr* cuando se considera el sistema y otras malezas. Todos los tratamientos estudiados fueron selectivos a la soja, que mostró mayores valores de daño en presencia de *diclosulam*; sin embargo, esto no comprometió el comportamiento agronómico de la soja.

Palabras clave

inhibidores de la ALS • *Glycine max* • inhibidores de la PROTOX • rama negra • malezas

Introduction

The hairy fleabane (*Conyza bonariensis*), horseweed (*Conyza canadensis*), and the Sumatran fleabane (*Conyza sumatrensis*) are among the most dominant weeds found worldwide. *C. sumatrensis* is believed to have originated in subtropical South America and subsequently dispersed to Europe, America, and Asia (11). It is an herbaceous plant with an annual life cycle and high seed production (9, 14), and it is found in various agricultural environments, such as grain crop fields (18). *Conyza* spp. disperses exclusively through seeds present in the achene. The number of seeds produced by a single plant varies from 100,000 to 200,000 (9). For *C. sumatrensis*, this number can be as high as 350,000 seeds produced during the plant cycle These seeds are positively photoblastic, and thus germinate only in the presence of light, a feature favored by direct sowing in straw, at temperatures below 28-30°C. The seeds germinate mainly from fall to early spring (33) in the off-season, before the sowing of soybeans.

A study by Trezzi *et al.* (2015) indicated that *C. bonariensis* can reduce soybean yield by 50% at a plant density of just 2.7 plants m^{-2}. Therefore, the adoption of control measures -most of which involve chemical control- is essential to prevent losses in crop yield. The three species of *Conyza* have 105 reported cases of biotypes resistant to herbicides, such as glyphosate, paraquat, and ALS inhibitors (12). In Brazil, the three species have been reported to be glyphosate resistant, with *C. sumatrensis* having seven records of resistance to herbicides, the largest number accounted for in the country. Moreover, there are reports of multiple resistance to glyphosate and chlorimuron (28), to paraquat (1), and to 2,4-D (27), among others. In this sense, an initial application of systemic herbicides, with sequential application of burndown and/or pre-emergent herbicides has proved to be effective and necessary, especially for large plants with a history of herbicide resistance (8, 12). Herbicides such as PROTOX or ALS-inhibiting herbicides can be used in sequential applications (12, 26, 34).

Considering the aggressiveness of *C. sumatrensis* and the increasing number of reports of biotypes resistant to glyphosate and other herbicides, the need for proactive management is apparent. The combination and rotation of systemic herbicides, with pre-emergence and/or burndown action during sequential application, are effective in controlling this weed species. In this context, the objective of this study was to evaluate the efficacy of different herbicides by analyzing the sequential application of saflufenacil/imazethapyr in soybean pre-sowing.

Material and Methods

Experiments 1 and 2 of the study were conducted in the field during the 2018-2019 growing season in the municipalities of Assis Chateaubriand (24°28'28.0" S 53°51'39.8" W) and Alto Piquiri, state of Paraná (PR), Brazil (24°06'27.01"S 53°45'35.07" W), respectively. According to the Köppen classification, the climate of the region is Cfa, and the weather conditions during the experimental period are illustrated in figures 1 and 2.

Aug 1, 2018 to Feb 06, 2019

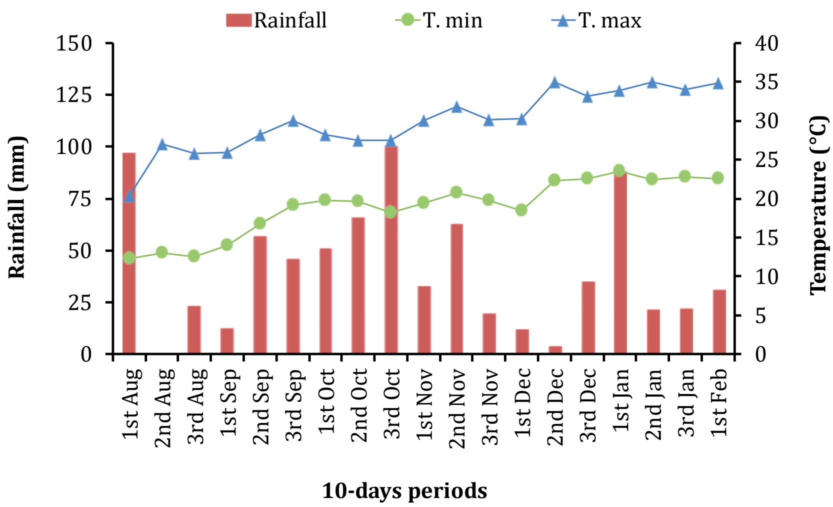

Figure 1. Rainfall and minimum and maximum temperatures for the experimental site Assis Chateaubriand (Experiment 1), 2018-19 growing season.

Figura 1. Representación de la lluvia, temperatura mínima y máxima para el sitio. Campaña 2018-19, Assis Chateaubriand (Experimento 1).

Aug 1, 2018 to Feb 06, 2019

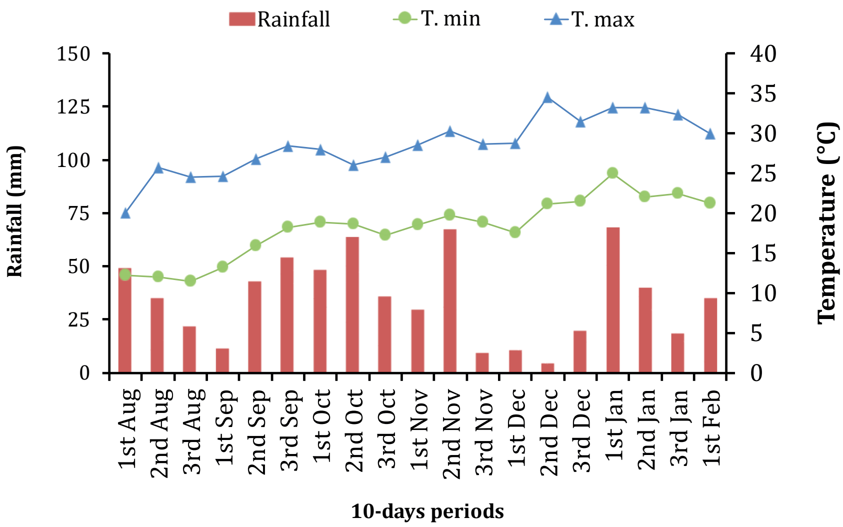

Figure 2. Representation of rainfall and minimum and maximum temperature for the test site Alto Piquiri (Experiment 2), 2018-19 growing season.

Figura 2. Representación de la lluvia, temperatura mínima y máxima para el sitio. Campaña 2018-19, Alto Piquiri (Experimento 2).

For experiment 1, the soil was classified as clayey (66.25% clay, 18.75% silt, and 15% sand), with the following chemical properties in the 0-20 cm layer: pH ($CaCl_2$) of 4.8, 2.23% organic matter (OM), and 11.85 $cmol_c$ dm^{-3} of cation exchange capacity (CEC). For experiment 2, the soil was classified as having a sandy loam texture (12.5% clay, 10% silt, and 77.5% sand), with a pH ($CaCl_2$) of 7.7, 1.39% OM, and 6.64 $cmol_c$ dm^{-3} of CEC.

Experimental site 1 was infested with *C. sumatrensis*, with a density of 6 plants m^{-2} (> 15 cm) and 11 plants m^{-2} (<15 cm), and approximately 55% of the *C. sumatrensis* population was resistant to paraquat. In experimental site 2, density was 8 plants m^{-2} (> 15 cm) and 2 plants m^{-2} (<15 cm), with approximately 10% of the *C. sumatrensis* population being resistant to paraquat. To determine the frequency of *C. sumatrensis* indicative of resistance to this herbicide, we applied paraquat (Gramoxone® 200) on tracks at label rate (400 g ai ha^{-1}) 14 days before the start of the experiment. Before and after application, the number of uncontrolled plants (≤20% control) with 6-10 leaves (4-8 cm in height) was evaluated and compared to the track where paraquat was not applied. Seven days after the application of paraquat, a second application was performed to determine the frequencies of resistance.

Previously, these areas had been cultivated with maize. Soybeans were sown under no-till, with 0.45 cm spacing between rows. Soybean cultivar Monsoy® 5917 IPRO (Monsanto Co. Brazil, São Paulo, SP, Brazil) was used in Experiment, 1 and Monsoy® 6410 IPRO (Monsanto Co. Brazil, São Paulo, SP, Brazil) in Experiment 2. The experiment was a randomized block design with four replicates. The treatments are presented in table 1. The dates of application, sowing, and environmental conditions during application are listed in table 2 (page 87). All applications were performed with a pressurized CO_2 backpack sprayer, equipped with six AIXR 110.015 nozzles, at a pressure of 2.5 kg * cm^{-2} and a speed of 3.6 km * h^{-1}, providing an application volume of 150 L * ha^{-1}.

Table 1. Treatments consisting of herbicide mixtures for controlling *Conyza sumatrensis* (2018-19 growing season).

Tabla 1. Tratamientos compuestos por mezclas de herbicidas para el control de *C. sumatrensis*. Campaña 2018-19.

	Treatments*	
	First application	**Sequential application**
1	Weedy control (no application)	No application
2	Glyphosate + 2,4-D + saflufenacil[1]	Paraquat[2]
3	Glyphosate + 2,4-D + saflufenacil[1]	Glyphosate + diclosulam
4	Glyphosate + 2,4-D + saflufenacil[1]	Flumioxazin/imazethapyr + paraquat[2]
5	Glyphosate + 2,4-D + saflufenacil[1]	Flumioxazin/imazethapyr[1]
6	Glyphosate + 2,4-D + saflufenacil[1]	Saflufenacil/imazethapyr + glyphosate[1]
7	Glyphosate + 2,4-D + saflufenacil[1]	Saflufenacil/imazethapyr + clethodim[1]
8	Glyphosate + 2,4-D + saflufenacil[1]	Glyphosate + imazethapyr[1]
9	Glyphosate + saflufenacil + diclosulam[1]	Saflufenacil/imazethapyr + glyphosate[1]
10	Glyphosate + diclosulam[1]	Saflufenacil/imazethapyr + glyphosate[1]
11	Glyphosate + 2,4-D[1]	Saflufenacil/imazethapyr + glyphosate[1]
12	Glyphosate + 2,4-D[1]	Glyphosate + diclosulam[1]

* Glyphosate (Zapp® QI 620 - 1,500 g ae ha^{-1}); 2,4-D (DMA® 806 BR - 670 g ae ha^{-1}); saflufenacil (Heat® - 35 g ai ha^{-1}); diclosulam (Spider® 840 WG - 25.2 g ai ha^{-1}); paraquat (Gramoxone® 200-400 g ai ha^{-1}); flumioxazin/imazethapyr (Zethamaxx® - 100/50 g ai/ae ha^{-1}); saflufenacil/imazethapyr (Optill® - 35.6/100.4 g ai/ae ha^{-1}); clethodim (Poquer® - 144 g ai ha^{-1}); imazethapyr (Vezir® 100-100 g ae ha^{-1}).

[1]Adjuvant Agral® (250 mL ha^{-1}) used. [2]Adjuvant Mees® (500 mL ha^{-1}) used.

* *glyphosate* (Zapp® QI 620 - 1,500 g ea ha^{-1}); 2,4-D (DMA® 806 BR - 670 g ea ha^{-1}); *saflufenacil* (Heat® - 35 g ia ha^{-1}); *diclosulam* (Spider® 840 WG - 25.2 g ia ha^{-1}); *paraquat* (Gramoxone® 200 - 400 g ia ha^{-1}); *flumioxazin/imazethapyr* (Zethamaxx® - 100/50 g ia/ea ha^{-1}); *saflufenacil/imazethapyr* (Optill® - 35.6/100.4 g ia/ea ha^{-1}); *clethodim* (Poquer® - 144 g ia ha^{-1}); *imazethapyr* (Vezir® 100 - 100 g ea ha^{-1}).

[1] Uso de adyuvante Agral® (250 mL ha^{-1}). [2] Uso de adyuvante Mees® (500 mL ha^{-1}).

Table 2. Dates and weather conditions during herbicide applications.
Tabla 2. Fechas y condiciones climáticas durante la aplicación de herbicidas.

	Date	Wind km h^{-1}	T. °C	Relative humidity %
Exp. 1 (first application)	Sep 10, 2018	6.2	24.2	57.0
Exp. 1 (sequential application)*	Sep 23, 2018	8.7	25.1	67.4
Exp. 2 (first application)	Sep 21, 2018	9.8	32.3	48.7
Exp. 2 (sequential application)*	Oct 4, 2018	2.8	31.2	58.9

* Day of sowing. / * Realizado el mismo día de la siembra.

The control of *C. sumatrensis* was evaluated at soybean sowing and 7, 21, and 35 days after the second application (DAA) of herbicides. Importantly, after the last control evaluation, all treatment plots were weeded except for the control. Injury to soybean plants was evaluated 14, 28, and 35 days after sowing (DAS), which was also performed in maize crops grown in succession areas. These evaluations were conducted through visual analysis at each experimental unit (0 for no injury, up to 100% for plant death), considering significantly visible symptoms in the plants according to their development (32).

Upon harvest, plant height and yield were evaluated. To evaluate the stand, the number of plants per meter was counted with four measurements per plot. Plant height was measured using a wooden ruler (10 plants per plot). For yield, the two central rows were harvested (4 m in length), moisture was corrected to 13%, and the results were extrapolated to kg ha^{-1}.

Analyses were performed using the statistical software Sisvar 5.6 (10). In addition, an analysis of variance (ANOVA) and an F-test ($P \leq 0.05$) were performed following Pimentel-Gomes and Garcia (2002), and mean treatment values were grouped using the Scott and Knott (1974) test ($P \leq 0.05$).

Results

For control evaluation at sowing, values of at least 91.5% were observed in Experiment 1 for the application of glyphosate + 2,4-D + saflufenacil and glyphosate + saflufenacil + diclosulam, The first evaluation was conducted 13 days after the first application, and the following evaluations included the effects of the two herbicides. In subsequent evaluations, all herbicide treatments resulted in the control of at least 90% *of C. sumatrensis*, with the exception of treatment 12. This treatment consisted of the first application of glyphosate + 2,4-D and the sequential application of glyphosate + diclosulam, and control at 35 DAA was only 56.8% (table 3, page 88).

The control results for *C. sumatrensis* in Experiment 2 were similar to those observed in Experiment 1. The highest percentages at soybean sowing were obtained for glyphosate + 2,4-D + saflufenacil and glyphosate + saflufenacil + diclosulam, with 75.3-87.5% of *C. sumatrensis* controlled. For the following evaluations, *C. sumatrensis* control of at least 80.3% (at 7 DAA) was recorded. At 35 DAA, with *C. sumatrensis* control between 93% and 99% in all evaluations, the only satisfactory control was found for treatment 12, which was 59.3% (table 4, page 88).

In Experiment 1, injury of up to 6% at 7 DAS was observed for treatments 3 (glyphosate + 2,4-D + saflufenacil sequential [*seq*.] glyphosate + diclosulam) and 12 (glyphosate + 2,4-D *seq*. glyphosate + diclosulam). However, a reduction in symptoms was observed in subsequent evaluations, even without any differences between treatments in the last evaluation at 35 DAS. Moreover, in the area of both experiments, maize was grown in the second crop (sowing in January 2019), and no crop injury was detected at 14, 28, and 35 DAS.

Table 3. *Conyza sumatrensis* control (%) after herbicide application. 2018-19 growing season, Assis Chateaubriand (Experiment 1).

Tabla 3. Control (%) de *C. sumatrensis* después de la aplicación de herbicidas. Campaña 2018-19, Assis Chateaubriand (Experimento 1).

Treatments			Sow	7 DAA	21 DAA	35 DAA
	First application	Sequential application	---------------%---------------			
1	Weedy control (no application)		0.0 d	0.0 d	0.0 c	0.0 c
2	Gly + 2,4-D + saflufenacil	Paraquat	91.5 a	92.0 b	93.3 a	92.5 a
3	Gly + 2,4-D + saflufenacil	Gly + diclosulam	92.3 a	93.0 b	97.3 a	96.8 a
4	Gly + 2,4-D + saflufenacil	Flumioxazin/imazethapyr + paraquat	93.5 a	94.8 a	95.3 a	94.8 a
5	Gly + 2,4-D + saflufenacil	Flumioxazin/imazethapyr	95.3 a	96.0 a	96.5 a	95.5 a
6	Gly + 2,4-D + saflufenacil	Saflufenacil/imazethapyr + gly	94.0 a	98.3 a	98.8 a	99.8 a
7	Gly + 2,4-D + saflufenacil	Saflufenacil/imazethapyr + clethodim	94.8 a	98.0 a	98.5 a	99.0 a
8	Gly + 2,4-D + saflufenacil	Gly + imazethapyr	92.0 a	95.3 a	96.8 a	94.8 a
9	Gly + saflufenacil + diclosulam	Saflufenacil/imazethapyr + gly	95.8 a	98.3 a	99.3 a	99.5 a
10	Gly + diclosulam	Saflufenacil/imazethapyr + gly	31.3 c	90.0 b	96.3 a	95.0 a
11	Gly + 2,4-D	Saflufenacil/imazethapyr + gly	44.0 b	92.0 b	97.3 a	96.8 a
12	Gly + 2,4-D	Gly + diclosulam	44.3 b	41.3 c	58.8 b	56.8 b
		Mean	72.2	82.3	85.6	85.1
		CV (%)	5.5	4.4	5.0	5.0
		F	*	*	*	*

Sow: sowing; DAA: day after sequential application; Gly: glyphosate. * Means followed by different letters in the same column are significantly different according to the Scott and Knott's (1974) test, $P \leq 0.05$.

Sow: siembra. DAA: día después de la aplicación secuencial. gly: *glyphosate*. * Las medias seguidas de la misma letra en la columna no difieren entre sí por Scott y Knott (1974), $P \leq 0,05$.

Table 4. *Conyza sumatrensis* control (%) after herbicide application. 2018-19 growing season, Alto Piquiri (Experiment 2).

Tabla 4. Control (%) de *C. sumatrensis* después de la aplicación de herbicidas. Campaña 2018-19, Alto Piquiri (Experimento 2).

Treatments			Sow	7 DAA	21 DAA	35 DAA
	First application	Sequential application	----------------%----------------			
1	Weedy control (without application)		0.0 d	0.0 d	0.0 d	0.0 c
2	Gly + 2,4-D + saflufenacil	Paraquat	75.8 b	83.5 b	85.0 b	96.5 a
3	Gly + 2,4-D + saflufenacil	Gly + diclosulam	76.8 b	80.3 b	83.8 b	96.3 a
4	Gly + 2,4-D + saflufenacil	Flumioxazin/imazethapyr + paraquat	83.0 a	90.8 a	93.3 a	96.5 a
5	Gly + 2,4-D + saflufenacil	Flumioxazin/imazethapyr	81.0 b	84.3 b	90.8 a	93.0 a
6	Gly + 2,4-D + saflufenacil	Saflufenacil/imazethapyr + gly	86.0 a	91.3 a	96.3 a	99.3 a
7	Gly + 2,4-D + saflufenacil	Saflufenacil/imazethapyr + clethodim	80.0 b	87.5 a	93.3 a	99.0 a
8	Gly + 2,4-D + saflufenacil	Gly + imazethapyr	75.3 b	81.0 b	87.5 b	94.3 a
9	Gly + saflufenacil + diclosulam	Saflufenacil/imazethapyr + gly	87.5 a	92.8 a	95.8 a	98.5 a
10	Gly + diclosulam	Saflufenacil/imazethapyr + gly	46.3 d	83.5 b	92.8 a	97.3 a
11	Gly + 2,4-D	Saflufenacil/imazethapyr + gly	57.5 c	82.0 b	89.5 b	96.5 a
12	Gly + 2,4-D	Gly + diclosulam	50.3 d	53.3 c	52.8 c	59.3 b
		Mean	66.6	75.8	80.0	85.5
		CV (%)	8.4	5.3	4.6	3.6
		F	*	*	*	*

Sow: sowing. DAA: day after sequential application. gly: glyphosate. * Means followed by different letters in the same column are significantly different according to the Scott and Knott's (1974) test, $P \leq 0.05$.

Sow: siembra. *DAA*: día después de la aplicación secuencial. gly: *glyphosate*. * Las medias seguidas de la misma letra en la columna no difieren entre sí por Scott y Knott (1974), $P \leq 0,05$.

In addition, no differences were found between treatments for plant height in Experiment 1. There was also a reduction in yield for the control, as well as for treatment 12, which resulted in the lowest control of *C. sumatrensis* and lowest soybean yield among all herbicide treatments. This may be because we used an earlier cycle cultivar and due to a water deficit in the first and second 10-day periods in December, with only 17 mm of rainfall and maximum average temperatures of 30.3°C and 35.1°C being observed during this time. For the control and treatment 12, in addition to weather conditions, competition with *C. sumatrensis* plants further reduced yield (table 5).

Table 5. Percentage of plant injury, height, and yield of soybean plants after herbicide application for control of *Conyza sumatrensis*. 2018-19 growing season, Assis Chateaubriand (Experiment 1).

Tabla 5. Daño al cultivo, altura y rendimiento de las plantas de soya después de la aplicación del herbicida, para el control de *C. sumatrensis*. Campaña 2018-19, Assis Chateaubriand (Experimento 1).

Treatments			Injury			H	Yield
			14 DAS	28 DAS	35 DAS		
	First application	Sequential application	----------%---------			cm	kg ha^{-1}
1	Weedy control (without application)		0.0 a	0.0 a	0.0	50.5	393 c
2	Gly + 2,4-D + saflufenacil	Paraquat	0.5 a	0.5 a	0.0	61.2	1,151 a
3	Gly + 2,4-D + saflufenacil	Gly + diclosulam	6.0 c	2.0 b	1.0	55.3	1,105 a
4	Gly + 2,4-D + saflufenacil	Flumioxazin/imazethapyr + paraquat	2.5 b	1.3 a	0.5	55.9	1,132 a
5	Gly + 2,4-D + saflufenacil	Flumioxazin/imazethapyr	2.5 b	1.0 a	0.8	56.9	1,071 a
6	Gly + 2,4-D + saflufenacil	Saflufenacil/imazethapyr + gly	1.5 a	1.5 b	0.0	58.3	1,171 a
7	Gly + 2,4-D + saflufenacil	Saflufenacil/imazethapyr + clethodim	2.5 b	1.8 b	0.5	59.9	1,126 a
8	Gly + 2,4-D + saflufenacil	Gly + imazethapyr	1.5 a	0.8 a	0.3	61.0	1,068 a
9	Gly + saflufenacil + diclosulam	Saflufenacil/imazethapyr + gly	3.3 b	2.0 b	0.8	59.8	1,095 a
10	Gly + diclosulam	Saflufenacil/imazethapyr + gly	3.5 b	1.3 a	0.8	57.3	1,081 a
11	Gly + 2,4-D	Saflufenacil/imazethapyr + gly	1.8 a	0.8 a	0.5	59.1	1,055 a
12	Gly + 2,4-D	Gly + diclosulam	6.0 c	2.8 b	1.3	60.0	789 b
		Mean	2.6	1.3	0.5	57.9	1,020
		CV (%)	14.5	19.3	19.5	6.6	12.2
		F	*	*	ns	ns	*

DAS: days after sowing; Gly: glyphosate; H: height. * Means followed by different letters in the same column are significantly different according to the Scott and Knott's (1974) test, $P \leq 0.05$. ns: non-significant, or means do not differ from each other according to the F-test ($P > 0.05$).

DAS: días después de la siembra. gly: *glyphosate*. *H:* altura. * Las medias seguidas de la misma letra en la columna no difieren entre sí por Scott y Knott (1974), $P \leq 0,05$. ns: no significativo, los medios no difieren entre sí por la prueba F ($P > 0,05$).

In Experiment 2, differences were detected between treatments in the three evaluations of injury to plants, with stronger symptoms (up to 5.3%) at 14 DAS and symptom reduction in the subsequent evaluations. At 35 DAS, the strongest symptoms were observed for treatments 3 and 12, as in Experiment 1, and for treatments 9 (glyphosate + saflufenacil + diclosulam *seq*. saflufenacil/imazethapyr + glyphosate) and 10 (glyphosate + diclosulam *seq*. saflufenacil/imazethapyr + glyphosate), with values of 3-3.5% injury. No differences were observed between treatments with respect to plant height. Differences in yield were observed, whereas in Experiment 1, reductions were observed in the control and treatment 12 due to competition with *C. sumatrensis* plants. The other herbicide treatments were superior to these two, but showed no significant differences from each other, with values of up to 4,104 kg ha^{-1} (table 6, page 90).

Table 6. Percentage of plant injury, height, and yield of soybean plants after herbicide application for the control of *Conyza sumatrensis*. 2018-19 growing season, Alto Piquiri (Experiment 2).

Tabla 6. Daño al cultivo, altura y rendimiento de las plantas de soja después de la aplicación del herbicida, para el control de *C. sumatrensis*. Campaña 2018-19, Alto Piquiri (Experimento 2).

Treatments			Injury			H	Yield
			14 DAS	28 DAS	35 DAS		
	First application	Sequential application	----------%----------			cm	kg ha^{-1}
1	Weedy control (without application)		0.0 a	0.0 a	0.0 a	66.3	2,567 b
2	Gly + 2,4-D + saflufenacil	Paraquat	0.0 a	0.0 a	0.0 a	83.1	3,924 a
3	Gly + 2,4-D + saflufenacil	Gly + diclosulam	5.3 d	3.5 c	3.0 b	77.8	4,076 a
4	Gly + 2,4-D + saflufenacil	Flumioxazin/imazethapyr + paraquat	1.3 b	0.3 a	0.0 a	75.4	3,944 a
5	Gly + 2,4-D + saflufenacil	Flumioxazin/imazethapyr	1.5 b	1.0 b	0.0 a	77.2	3,943 a
6	Gly + 2,4-D + saflufenacil	Saflufenacil/imazethapyr + gly	2.5 c	1.8 b	0.8 a	75.7	3,906 a
7	Gly + 2,4-D + saflufenacil	Saflufenacil/imazethapyr + clethodim	2.8 c	1.8 b	0.8 a	75.1	3,994 a
8	Gly + 2,4-D + saflufenacil	Gly + imazethapyr	1.5 b	0.5 a	0.0 a	75.9	4,104 a
9	Gly + saflufenacil + diclosulam	Saflufenacil/imazethapyr + gly	5.0 d	3.8 c	3.0 b	74.1	4,067 a
10	Gly + diclosulam	Saflufenacil/imazethapyr + gly	4.5 d	3.8 c	3.0 b	73.1	4,035 a
11	Gly + 2,4-D	Saflufenacil/imazethapyr + gly	1.3 b	0.8 a	0.3 a	75.0	3,865 a
12	Gly + 2,4-D	Gly + diclosulam	5.3 d	4.0 c	3.5 b	73.7	3,101 b
		Mean	2.6	1.8	1.2	75.2	3,794
		CV (%)	8.6	13.0	11.2	6.4	9.7
		F	*	*	*	ns	*

DAS: days after sowing; Gly: glyphosate; H: height. * Means followed by different letters in the same column are significantly different according to the Scott and Knott's (1974) test, $P \leq 0.05$. ns: non-significant, or means do not differ from each other according to the F-test ($P > 0.05$).

DAS: días después de la siembra. gly: *glyphosate*. *H:* altura. * Las medias seguidas de la misma letra en la columna no difieren entre sí por Scott y Knott (1974), $P \leq 0,05$. ns: no significativo, los medios no difieren entre sí por la prueba F ($P > 0,05$).

Discussion

In both experiments, treatments with sequential application of saflufenacil/ imazethapyr and flumioxazin/imazethapyr were among the most effective in controlling *C. sumatrensis*. According to Hedges *et al.* (2019), the pre-sowing application of dicamba/ glyphosate (1,800 g ae ha^{-1}) + saflufenacil (25 g ai ha^{-1}) or saflufenacil/imazethapyr (100 g ae ha^{-1}) was effective in controlling *C. canadensis*, with results of ≥91% (12 weeks after application). Similarly, Cantu *et al.* (2021) reported the effectiveness of dicamba, in combination with other herbicides, in the control of *C. sumatrensis.* Moreover, Hedges *et al.* (2019) observed up to 10% soybean injury with the application of saflufenacil in different chemical management programs; however, the symptoms did not result in reduced soybean yield, thus demonstrating that the application of saflufenacil is effective in different management programs to control *Conyza* spp. (4, 7, 15, 16, 17, 34). Other studies also demonstrated, as in the present study, the efficacy of flumioxazin in different combinations for the control of *Conyza* spp. (20, 23, 26, 34).

In this study, the application of treatment 12 (glyphosate + 2,4-D *seq.* glyphosate + diclosulam) was not satisfactorily effective in controlling *C. sumatrensis* in both experiments; rather, it was the most phytotoxic treatment to soybean plants, with up to 6% at 14 DAA, as observed in Experiment 1. From a control point of view, an additional post-emergence application is necessary for soybean. Neto *et al.* (2009) observed an injury of 2.2% in soybean plants treated with glyphosate (960 g ae ha^{-1}) + diclosulam (35 g ai ha^{-1}) at the V1 stage. These symptoms did not affect soybean yield, indicating the selectivity of the combination.

Furthermore, soil and climate conditions interfere with the effects of diclosulam and other pre-emergents on soybean; for example, high rainfall after application can increase soybean injury (8), which may explain what was observed in the present study. According to Pereira *et al.* (2000) and Osipe *et al.* (2014), the application of diclosulam to soybean was selective, alone or in combination with glyphosate, although some symptoms of injury were observed.

The results presented herein demonstrate the importance of herbicide application before soybean sowing for the effective control of *C. sumatrensis*. The use of systemic herbicides in the first application, as well as the sequential application of burndown herbicides, is essential for the control of large plants (>15 cm height), notably saflufenacil and flumioxazin (PROTOX inhibitors), in addition to imazethapyr (ALS inhibitor) herbicides. These herbicides are also effective in controlling other weeds, especially broadleaf weeds such as *Amaranthus* spp., *Ipomoea* spp., and *Commelina* spp., and imazethapyr has been shown to act on *Digitaria insularis*, *D. horizontalis*, and other monocotyledons. Furthermore, our results indicate the effectiveness of the sequential application of these herbicides in controlling *C. sumatrensis*, which is relevant as they might contribute to supporting the ban on paraquat in Brazil.

Finally, control of *Conyza* spp. and other weeds cannot be left solely to glyphosate, as this genus has 66 cases of glyphosate-resistant biotypes worldwide. For instance, in Brazil, *Lolium perenne* ssp. *multiflorum*, *C. bonariensis, C. sumatrensis*, *C. canadensis*, *D. insularis*, *Chloris elata*, *Amaranthus palmeri*, *Eleusine indica*, and *Amaranthus hybridus* have glyphosate-resistant biotypes (12). Thus, the use of other herbicides, such as ALS inhibitors, auxinics, and glufosinate, should be considered. This is especially true for combinations and weed management during the off-season, as studies have highlighted the efficacy of pre-emergence herbicides along with pre-sowing burndown for weed management in grain crops (2, 3, 5, 21, 31).

Conclusion

Control levels were high for all the herbicide treatments, except for the one that was free of saflufenacil in both applications. These results highlight the importance of saflufenacil in controlling *C. sumatrensis* and show promise for saflufenacil/imazethapyr considering the system and other weeds. Finally, all studied treatments were selective to soybean, which showed higher injury values in the presence of diclosulam; however, this did not compromise soybean agronomic performance.

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