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Original Article

Soybean grown in lowland rice areas to reduce weed infestation[1]

Cultivo de soja em área de arroz irrigado para reduzir a infestação de plantas daninhas

Filipe C. Cardoso[2*], Mayra L. Schelter[2], Jessiane M. Jastrombek[2], Leonardo M. da C. Silva[3], Anderson G. Ambrasson[3], Naiara Guerra[4] & Antonio M. de Oliveira Neto[5]

[1] Research developed at Universidade do Estado de Santa Catarina, Centro de Ciências Agroveterinárias, Lages, SC, Brazil
[2] Universidade do Estado de Santa Catarina/Programa de Pós-graduação em Produção Vegetal, Lages, SC, Brazil
[3] Universidade do Estado de Santa Catarina/Curso de Agronomia, Lages, SC, Brazil
[4] Universidade Federal de Santa Catarina/Centro de Curitibanos, Curitibanos, SC, Brazil
[5] Universidade do Estado de Santa Catarina/Departamento de Agronomia, Lages, SC, Brazil

HIGHLIGHTS:

The exclusive application of pre-emergence herbicides was not effective in controlling barnyard grass and other weed species.
Glyphosate (1,550 g a.e. ha^{-1}) + clethodim was effective in controlling barnyard grass.
S-metolachlor, diclosulam, and pyroxasulfone + flumioxazin plus glyphosate were selective and effective.

ABSTRACT: Lowland rice in Santa Catarina (SC), Brazil, is grown as a sole crop, which has aggravated problems with weeds. In this context, the objective of this study was to evaluate the efficacy of weed management systems in soybean crops to decrease weed infestation in lowland rice production areas, using pre- and post-emergence herbicides. The experiment was conducted in Turvo, SC, from August 2021 to April 2022. A randomized block design with four replications was used, in a 6 × 5 factorial arrangement. The factors consisted of six pre-emergence herbicides treatments (S-metolachlor, diclosulam, sulfentrazone, sulfentrazone + diuron, pyroxasulfone + flumioxazin, and a control without herbicide), and five post-emergence herbicide treatments: control without herbicide, glyphosate at two rates (930 and 1,550 g a.e. ha^{-1}), applied alone or in combination with clethodim. The herbicide sulfentrazone caused persistent phytotoxicity and resulted in the lowest soybean grain yield. The herbicide S-metolachlor was ineffective in controlling weed species, except barnyard grass, even when combined with post-emergence application. The poor control of these weed species does not result in significant interference, causing no significant decreases in grain yield of soybean crops grown in floodplain soils. The use of S-metolachlor, diclosulam, and pyroxasulfone + flumioxazin, combined with post-emergence application of glyphosate (930 g a.e. ha^{-1}), resulted in highly effective control of barnyard grass, inhibiting weed seed production. Only the combination of glyphosate (1,550 g a.e. ha^{-1}) with clethodim can suppress barnyard grass seed production without using pre-emergence herbicides.

Key words: *Echinochloa crus-galli*; *Glycine max*; pre-emergence; crop rotation; management systems

RESUMO: O arroz irrigado em Santa Catarina é cultivado em monocultivo, o que tem agravado os problemas com plantas daninhas. Deste modo, o objetivo deste estudo foi avaliar a eficiência de sistemas de manejo de plantas daninhas na cultura da soja sobre a redução da infestação de plantas daninhas em uma área de produção de arroz irrigado, utilizando para isso herbicidas em pré e/ou pós-emergência da soja. O experimento foi conduzido no município de Turvo - SC no período de agosto de 2021 a abril de 2022. Utilizou-se o delineamento de blocos casualizados com tratamentos organizados em esquema fatorial 6 × 5, com quatro repetições. O fator A constou de seis tratamentos aplicados em pré-emergência, os herbicidas utilizados foram: S-metolachlor, diclosulam, sulfentrazone, sulfentrazone + diuron, pyroxasulfone + flumioxazin, além de uma testemunha sem herbicida. Já o fator B constou de cinco tratamentos aplicados em pós-emergência: testemunha sem herbicida, gyphosate em duas doses (930 e 1550 g e.a. ha^{-1}), aplicadas de forma isoladas ou em associação com clethodim. O herbicida S-metolachlor foi ineficiente para o controle de outras plantas daninhas, mesmo quando combinado com a aplicação em pós-emergência. O controle deficiente destas espécies não resulta em significativa interferência, não causando decréscimo na produtividade de grãos da soja, em ambientes de terras baixas. O uso dos herbicidas S-metolachlor, diclosulam e pyroxasulfone + flumioxazin, combinados com a aplicação em pós-emergência de glyphosate (930 g e.a. ha^{-1}) resultou em controle eficiente de capim-arroz e inibiu a produção de sementes. Apenas a associação de glyphosate (1550 g e.a. ha^{-1}) com clethodim suprimiu a produção de sementes de capim-arroz, sem a aplicação de herbicidas em pré-emergência.

Palavras-chave: *Echinochloa crus-galli*; *Glycine max*; pré-emergência; rotação de culturas; sistemas de manejo

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* Corresponding author - E-mail: filipeccardoso@gmail.com
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Introduction

Weedy rice became the main infesting weed in 80% of municipalities in the state of Rio Grande do Sul, Brazil, as early as the 1990s. This infestation hindered the quality and yield of crops and resulted in a worrisome increase in the soil seed bank over the years (Marchezan, 1994).

Thus, the pre-germination production system, predominant in the state of Santa Catarina, became an alternative to decrease the seed bank. However, despite it was efficient, it did not provide total control of emergence of weedy rice (Vargas et al., 2023) and other harmful species to the crop, including *Echinochloa* spp. In addition, other weed species also evolved to grow under hypoxia (oxygen deficiency) or anoxia (oxygen absence) conditions, which hindered the use of water as a physical barrier for controlling weeds in this environment (Kaspary et al., 2020).

Thus, areas intended exclusively for lowland rice crops have become economically unviable due to resistance of these species to current control methods (Rubin et al., 2014). In this regard, crop rotation with soybeans has increased, ensuring the sustainability of the system (Avila et al., 2021; Concenço et al., 2022).

Currently, the goal is not only to control weeds in rice and soybean rotation areas, but also to reduce the seed bank to make the maintenance of lowland rice crops increasingly viable. Farmers have been growing soybean crops to manage weeds in irrigated rice areas and diversify their sources of rural income, which has enabled the use of herbicides with different mechanisms of action than those used for rice crops (Agostinetto et al., 2018). Application of nonselective herbicides before sowing or after the emergence of transgenic crops, as well as the combination of pre- and post-emergence herbicide applications, along with complementary management practices are essential for reducing the soil seed bank (Avila et al., 2021). Freitas et al. (2022) confirmed that the use of pre-emergence herbicides for soybean crops is an effective tool in weed management in floodplain areas grown in rotation with rice crops, mainly for barnyard grass management.

The objective of this study was to evaluate the efficacy of weed management systems in soybean crops in decreasing weed infestation in lowland rice production areas in the south coastal region of the state of Santa Catarina, Brazil, using pre- and post-emergence herbicides.

Material and Methods

The experiment was carried out at the experimental unit of the Dagostin Seeds, in the municipality of Turvo, SC, Brazil (28° 54' 9.9" S, 49° 44' 39.8" W, and altitude of 49 meters). The climate of the region is Cfa, humid subtropical (mesothermal humid, with hot summer), without a well-defined dry season, according to the Köppen classification (Back, 2020). A field experiment was carried out in a systematized floodplain area that has a history of high infestation of weedy rice and barnyard grass with resistance to acetolactate synthase (ALS) inhibitors. Fieldwork was carried out from August 21, 2021, when soil preparation was started, to April 26, 2022, when the experimental plots were harvested. Information about the weather conditions during the experimental period are shown in Figure 1.

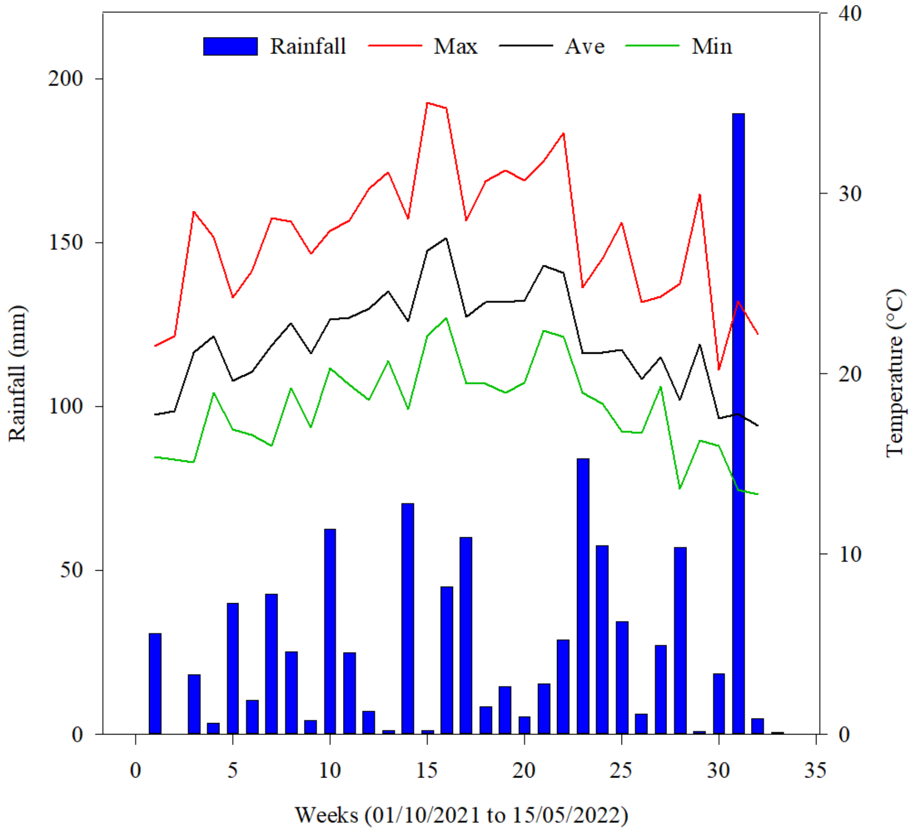


Figure 1. Maximum (Max), average (Ave), and minimum (Min) temperatures and rainfall depths in Turvo, SC, Brazil, from October 1, 2021 to May 15, 2022

The soil of the experimental area was classified as Gleissolo Haplico tb eutrofico (Santos et al., 2018), corresponding to an Entisol, according to the USDA Soil Taxonomy Classification (Soil Survey Staff, 2014). In the crop season 2021/2022, the soil (0-20 cm layer) was analyzed in August 2021 and presented the following physical and chemical attributes: 36 dag kg^{-1} clay; pH water (1:1) = 5.3; P = 3.4 mg dm^{-3}; K = 153 mg dm^{-3}; Al = 0.3 cmol$_c$ dm^{-3}; Ca = 4.6 cmol$_c$ dm^{-3}; Mg = 2.7 cmol$_c$ dm^{-3}; 2.4% organic matter; and aluminum saturation = 3.2%.

The study was carried out in an area systematized for lowland rice production that was adequate for crop rotation systems. The soil of the area was prepared soon after the maize harvest (preceding crop). The soil across the entire area was loosened in late July 2021, using a scarifier equipped with four shanks spaced 50 cm apart to a depth of 35 cm. A drag-type leveling disc harrow was used to remove irregularities caused by the previous operation and improve the systematization of the area.

A burndown of weeds was carried out on August 25, 2021, due to the high weed infestation, using glyphosate (2,480 g a.e. ha^{-1}) + 2,4-D (402 g a.i. ha^{-1}) + and alkyl ester phosphate adjuvant (376 g a.i. ha^{-1}). The soil was then subjected to a light harrowing one day before sowing to incorporate plant residues.

The experiment was conducted in a randomized block design with four replications, in a 6 × 5 factorial arrangement. The first factor consisted of six pre-emergence herbicide treatments: S-metolachlor (1,728 g a.i. ha^{-1}), diclosulam (29.4 g a.i. ha^{-1}), sulfentrazone (500 g a.i. ha^{-1}), sulfentrazone + diuron (210 + 420 g a.i. ha^{-1}), pyroxasulfone + flumioxazin (120 + 80 g a.i. ha^{-1}), and a control without pre-emergence herbicide application. The second factor consisted of five post-emergence herbicide treatments: control without herbicide, and glyphosate at two rates (930 and 1,550 g a.e. ha^{-1}), applied alone or combined with clethodim (108 g a.i. ha^{-1}). A total of 30 treatments were evaluated; the area of each experimental unit was 3 × 4 m, totaling an area of 12 m^2.

Soybean seeds of the cultivar BS 2606 IPRO were sown on November 01, 2021. A 6-row seeder was used, with spacing between rows of 0.50 m and density of 13 seeds per linear meter. The final plant population was approximately 260,000 plants ha^{-1}. The seeds were treated with pyraclostrobin + thiophanate-methyl + fipronil (2.0 mL kg^{-1}) and inoculated with *Bradyrhizobium japonicum* (SEMIA 5079 and 5080) at 5×10^9 CFU mL^{-1} (7.5 mL kg^{-1}). Soil fertilizers were applied at sowing by applying 147 kg ha^{-1} of P_2O_5 to the sowing furrow; 60 kg of K_2O ha^{-1} were broadcasted two days after sowing (SBCS, 2016).

The soybean crop was conducted under conventional tillage system. Pest and disease managements were carried out through chemical control, following technical recommendations for commercial areas in the region, using approved pesticides for soybean crops by the Brazilian Ministry of Agriculture and Livestock. The soybean plants thrived in a rainfed system, with all their water needs naturally supplied by rainfall (Figure 1).

The treatments were applied using a CO_2-pressurized backpack sprayer equipped with four nozzles (TT 110.015), under constant pressure of 207 kPa, monitored through a pressure gauge in the spray boom, and speed of 1.0 m s^{-1}; the rate was equivalent to 150 L ha^{-1}. The pre-emergence application (first factor) was carried out in the plant-and-apply system, on the day of sowing. The climatic conditions at the time of application were: average temperature of 25 °C, average relative air humidity of 71%, and average wind speed of 5.0 km h^{-1}.

The post-emergence application (second factor) was carried out 34 days after sowing, on December 04, 2021, when the soybean was at the V5/V6 stage and the weeds had three to four fully expanded leaves. The climatic conditions at the time of application were: average temperature of 27.5 °C, average relative air humidity of 55%, and average wind speed of 2.7 km h^{-1}.

Weed control and phytotoxicity in soybean plants were evaluated at 34 days after sowing, on the same day that the post-emergence application was carried out. A visual scale of grades from 0 to 100% was used to evaluate the weed control, where 0% means no control and 100% means total control (death) of weeds. A visual scale of grades from 0 to 100% was also used to evaluated phytotoxicity in soybean plants, where 0% means no injury and 100% means total necrosis of the plant (Hay et al., 2019). Phytotoxicity evaluations were carried out at 0, 7, 14, and 34 days after post-emergence application (DAA). Weed control was evaluated at 0, 7, 14 ,34, and 111 DAA. Barnyard grass and various other weed species were targeted in the weed control assessments. Barnyard grass, the dominant species, was uniformly distributed throughout the experimental area. The other weed species (weedy rice, billygoat weed, and oval-leaf false-buttonweed) were collectively evaluated due to their irregular distribution in the area.

The weeds were counted at 34 DAA. The final plant stand was estimated by counting the number of soybean plants in the three central rows, in four linear meters of each plot. Plant heights were defined by measuring the height of five plants per plot. The number of pods per plant was determined by counting the number of pods on five plants per plot. These evaluations were performed at pre-harvest (111 DAA).

Grain yield was assessed by manually harvesting plants from four meters of the three central rows of the plot using a gasoline-powered brush cutter. Harvested plants were bagged and labeled before threshing in a stationary machine. Grain moisture content was measured and adjusted to 13%; grain yield was converted to kg per hectare (kg ha^{-1}).

Barnyard grass seed production was evaluated at pre-harvest. The panicles within an area of 0.25 m^2, measured with a frame, were harvested, and dried in a forced air circulation oven at 38 °C for 72 hours. They were then manually threshed and weighed to determine the total weight of seeds in each plot. The total number of seeds per square meter was estimated by counting the total number of seeds in 0.5 g samples and extrapolating it to the number of barnyard grass seeds per square meter.

The 1000-grain weight was determined by drying the samples in a forced air circulation oven at 38 °C, measuring the 1000-grain weight. Grain moisture content was measured and adjusted to 13%.

The data were subjected to analysis of variance by the F test. The factors (pre-emergence and post-emergence treatments) were subjected to statistical breakdown, and the means were compared by the Tukey's test, except for barnyard grass seed production, which was evaluated through confidence interval. The significance level used in all analyses was $p \le 0.05$.

Results and Discussion

The first visual evaluation of phytotoxicity was carried out 33 days after sowing, when using post-emergence application (Table 1), which was considered as 0 DAA. The herbicides S-metolachlor and diclosulam presented phytotoxicity levels less than 5%; the symptoms were leaf wrinkling in some leaves and light chlorosis, respectively.

Similar injury symptoms to those caused by the herbicide diclosulam were found by Sanchotene et al. (2016) at 21 DAA; the phytotoxicity was very light in the soybean crop. However, their results for the herbicide S-metolachlor diverged from those found in the present study; the absence of symptoms found by them may be connected to the S-metolachlor rate used (1152 g a.i. ha^{-1}).

Gubiani et al. (2021) evaluated the effect of different rates of sulfentrazone + diuron on soybean crops and found no phytotoxic symptoms regardless of the rates applied. These results differ from those found in the present study for sulfentrazone + diuron application, which resulted in visual lesions and maximum phytotoxicity of 12.5%. Variations in soil pH, texture, and organic matter should be considered as factors that can affect the sorption of the herbicides sulfentrazone and diuron to soil colloids (Inoue et al., 2008; Freitas et al., 2014).

The highest phytotoxicity was found for the herbicide sulfentrazone, presenting values between 24.25% and 33.25% (Table 1). High phytotoxicity (>20% at 33 DAA) in soybean crops, varying mainly as a function of the cultivar used, was found by Taylor-Lovell et al. (2001) for sulfentrazone rates higher than 224 g a.i. ha^{-1}. The main symptoms were reduced growth, small leaves, limited development, and plant stand problems, similar symptoms to those described by Arruda et al. (1999). This result was found in the subsequent evaluation, at 14 DAA; most treatments presented phytotoxicity next to zero, while sulfentrazone presented phytotoxicity higher than 14%. Treatments with sulfentrazone presented injuries higher than 10% at 34 DAA (Table 1). Similar results were found by Pereira et al. (2000), who evaluated sulfentrazone application to soybean crops grown in a sandy soil.

It is not clear whether the injuries found in this study were due to the cultivar or environmental conditions. Thus, further studies evaluating the herbicide sulfentrazone and the susceptibility of soybean cultivars used in the region are recommended.

The post-emergence application of glyphosate had no phytotoxic effect on soybean crops, regardless of the rate and

Table 1. Phytotoxicity (%) in soybean plants at 0, 7, 14, and 34 days after post-emergence application (DAA) of herbicides

Pre-emergence	Post-emergence				
	Without herbicide	G930	G1550	G930 + C	G1550 + C
			Phytotoxicity at 0 DAA		
Without herbicide	0.0 dA	0.0 bA	0.0 cA	0.0 cA	0.0 cA
S-metolachlor	1.2 cdA	0.7 bA	0.5 cA	4.2 bcA	1.5 bcA
Diclosulam	0.5 cdA	1.2 bA	1.5 cA	1.7 cA	0.0 cA
SUL	33.2 aA	27.2 aAB	31.5 aAB	30.5 aAB	24.2 aB
SUL + Diuron	12.5 bA	4.2 bA	5.5 bcA	6.7 bcA	5.0 bcA
PYR + FLU	9.2 bcA	8.0 bA	11.0 bA	11.7 bA	9.5 bA
CV (%)			52.6		
			Phytotoxicity at 7 DAA		
Without herbicide	0.0 bA	0.7 bA	0.5 bA	0.0 cA	1.2 bA
S-metolachlor	0.0 bA	1.5 bA	3.2 bA	2.5 cA	1.2 bA
Diclosulam	0.0 bA	3.0 bA	1.7 bA	0.0 cA	2.5 bA
SUL	25.2 aA	21.5 aA	23.7 aA	23.7 aA	20.0 aA
SUL + Diuron	5.7 bA	0.5 bA	2.0 bA	1.7 cA	0.0 bA
PYR + FLU	4.0 bA	3.0 bA	6.5 bA	9.0 bA	5.0 bA
CV (%)			55.3		
			Phytotoxicity at 14 DAA		
Without herbicide	0.0 bA	0.0 bA	0.0 bA	0.0 bA	0.0 bA
S-metolachlor	0.0 bA	0.0 bA	1.2 bA	0.0 bA	0.0 bA
Diclosulam	0.0 bA	0.0 bA	0.0 bA	0.0 bA	0.0 bA
SUL	19.0 aA	14.2 aC	17.5 aAB	16.0 aABC	14.7 aBC
SUL + Diuron	2.0 bA	0.0 bA	0.0 bA	0.0 bA	0.0 bA
PYR + FLU	0.0 bA	0.0 bA	0.5 bA	2.7 bA	0.7 bA
CV (%)			52.9		
			Phytotoxicity at 34 DAA		
Without herbicide	0.0 bA	0.0 bA	0.0 bA	0.0 bA	0.0 bA
S-metolachlor	0.0 bA	0.0 bA	0.0 bA	0.0 bA	0.0 bA
Diclosulam	0.0 bA	0.0 bA	0.0 bA	0.0 bA	0.0 bA
SUL	11.2 aA	10.0 aA	11.2 aA	11.2 aA	11.2 aA
SUL + Diuron	0.0 bA	0.0 bA	0.0 bA	0.0 bA	0.0 bA
PYR + FLU	0.0 bA	0.0 bA	0.0 bA	0.0 bA	0.0 bA
CV (%)			47.1		

Means followed by the same lowercase letter in the columns (Pre-emergence) or uppercase letter in the rows (Post-emergence) are not significantly different from each other by the Tukey's test ($p > 0.05$). SUL - Sulfentrazone, PYR - Pyroxasulfone, FLU - Flumioxazin, G930 - Glyphosate at 930 g a.e. ha^{-1}, G1550 - Glyphosate at 1,550 g a.e. ha^{-1}, and C - Clethodim combination with clethodim. Similar results were reported by Alencar et al. (2022).

All treatments presented satisfactory control of barnyard grass at 0 DAA, varying from 82.5 to 100% (Table 2). Treatments with pre-emergence herbicides had higher control efficacy than treatments with only post-emergence application, with no significant difference between herbicides at 7 DAA (Table 2). The control of barnyard grass was higher than 87% at 14 DAA in all treatments combining pre- and post-emergence applications (Table 2). The applications of S-metolachlor alone and pyroxasulfone + flumioxazin presented similar results, whereas diclosulam and sulfentrazone + diuron had performances lower than 90% when applied alone. Pre-emergence herbicides applied alone were not effective in controlling barnyard grass in soybeans crops at pre-harvest (111 DAA), with control efficacy below 80% (Table 2).

Post-emergence application yielded significantly similar results to the other treatments only when combining glyphosate at 1,550 g a.e. ha^{-1} + clethodim, the control was similar to the other treatments that combined pre- and post-emergence applications (Table 2). Considering that the same rate of clethodim was used in combination with two different rates of glyphosate (930 and 1,550 g a.e. ha^{-1}), the control efficacy may be attributed to the increase in the glyphosate rate. According to Christoffoleti & Lopez-Ovejero (2003), ryegrass resistance to glyphosate is not absolute, as increasing the herbicide rate can control these biotypes.

Gubani et al. (2021) reported the importance of supplementing treatments with post-emergence application to control weeds emerging after the residual period of pre-emergence herbicides applied.

S-metolachlor was ineffective in controlling other weed species, mainly those from the Magnoliopsida class (broadleaf). The application of this herbicide alone resulted in a control of only 16% for these species (Table 3). All combinations with S-metolachlor and post-emergence herbicides showed control of other weed species lower than 67.5%. The other treatments were effective, with control levels higher than 87%. The pre-harvest assessment of diclosulam and sulfentrazone + diuron showed over 90% control of other species, but was

Table 2. Control of barnyard grass at 0, 7, 14, 34, and 111 days after post-emergence application (DAA) of herbicides

Pre-emergence	Post-emergence				
	Without herbicide	G930	G1550	G930 + C	G1550 + C
			Control of barnyard grass at 0 DAA		
Without herbicide	0.0 bA	0.0 bA	0.0 bA	0.0 bA	0.0 bA
S-metolachlor	99.0 aA	89.2 aA	87.0 aA	99.5 aA	85.5 aA
Diclosulam	93.0 aA	87.7 aA	83.2 aA	93.2 aA	92.7 aA
SUL	99.5 aA	99.5 aA	97.5 aA	99.2 aA	100.0 aA
SUL + Diuron	88.2 aA	83.7 aA	82.5 aA	90.2 aA	87.2 aA
PYR + FLU	94.2 aA	93.7 aA	96.2 aA	98.7 aA	99.7 aA
CV (%)			12.3		
			Control of barnyard grass at 7 DAA		
Without herbicide	0.0 bD	43.7 bC	75.0 bAB	67.5 bB	89.2 aA
S-metolachlor	100.0 aA	90.2 aA	95.0 aA	100.0 aA	93.0 aA
Diclosulam	92.5 aA	93.2 aA	95.2 aA	100.0 aA	100.0 aA
SUL	100.0 aA	100.0 aA	99.2 aA	100.0 aA	100.0 aA
SUL + Diuron	89.5 aA	94.0 aA	95.5 aA	98.2 aA	97.5 aA
PYR + FLU	95.0 aA	96.2 aA	99.0 aA	99.7 aA	100.0 aA
CV (%)			8.2		
			Control of barnyard grass at 14 DAA		
Without herbicide	0.0 dC	67.5 cB	92.5 aA	93.7 aA	98.2 aA
S-metolachlor	97.0 abAB	87.5 bB	100.0 aA	100.0 aA	100.0 aA
Diclosulam	87.0 bcB	97.5 abAB	100.0 aA	100.0 aA	100.0 aA
SUL	98.5 aA	100.0 aA	100.0 aA	100.0 aA	100.0 aA
SUL + Diuron	81.2 cB	96.2 abA	100.0 aA	100.0 aA	99.5 aA
PYR + FLU	92.0 abcA	98.7 abA	100.0 aA	100.0 aA	100.0 aA
CV (%)			5.9		
			Control of barnyard grass at 34 DAA		
Without herbicide	0.0 dC	75.0 bB	88.7 aAB	93.0 aA	95.0 aA
S-metolachlor	89.7 abA	98.7 aA	99.0 aA	99.5 aA	99.2 aA
Diclosulam	76.0 bcB	98.5 aA	93.7 aA	99.0 aA	98.5 aA
SUL	92.7 aA	98.7 aA	100.0 aA	99.2 aA	99.7 aA
SUL + Diuron	61.2 cB	96.5 aA	98.2 aA	98.5 aA	97.2 aA
PYR + FLU	83.7 abB	99.2 aAB	97.7 aAB	99.2 aAB	100.0 aA
CV (%)			8.8		
			Control of barnyard grass at 111 DAA (Pre-harvest)		
Without herbicide	0.0 cC	68.7 bB	73.0 bB	90.0 aAB	99.5 aA
S-metolachlor	71.2 aB	99.2 aA	99.7 aA	96.0 aA	99.7 aA
Diclosulam	64.2 abB	100.0 aA	98.5 aA	99.2 aA	100.0 aA
SUL	71.2 aB	97.0 aA	97.7 aA	99.5 aA	99.5 aA
SUL + Diuron	42.2 bB	90.5 abA	98.5 aA	98.7 aA	99.2 aA
PYR + FLU	79.2 aA	97.5 aA	98.2 aA	99.0 aA	98.2 aA
CV (%)			12.7		

Means followed by the same lowercase letter in the columns (Pre-emergence) or uppercase letter in the rows (Post-emergence) are not significantly different from each other by the Tukey's test ($p > 0.05$). SUL - Sulfentrazone, PYR - Pyroxasulfone, FLU - Flumioxazin, G930 - Glyphosate at 930 g a.e. ha^{-1}, G1550 - Glyphosate at 1,550 g a.e. ha^{-1}, and C - Clethodim

Table 3. Control of other weed species (weedy rice + billygoat weed + oval-leaf false-buttonweed) at 0, 7, 14, 34, and 111 days after post-emergence application (DAA) of herbicides

Pre-emergence	Post-emergence				
	Without herbicide	G930	G1550	G930 + C	G1550 + C
Control of other weed species at 0 DAA					
Without herbicide	0.0 cA	0.0 cA	0.0 aA	0.0 aA	0.0 aA
S-metolachlor	78.5 bA	74.5 bA	75.7 bA	83.7 bA	87.0 aA
Diclosulam	99.5 aA	98.7 aA	97.5 aA	100.0 aA	98.5 aA
SUL	95.2 aA	95.2 aA	97.5 aA	98.5 abA	97.0 aA
SUL + Diuron	88.5 abA	90.0 abA	93.0 aA	94.0 abA	93.2 aA
PYR + FLU	100.0 aA	97.2 aA	97.2 aA	98.5 abA	96.2 aA
CV (%)			9.8		
Control of other weed species at 7 DAA					
Without herbicide	0.0 cC	67.5 bB	90.5 aA	91.7 aA	89.2 aA
S-metolachlor	70.7 bB	90.0 aA	95.7 aA	100.0 aA	98.2 aA
Diclosulam	99.2 aA	95.0 aA	92.5 aA	100.0 aA	100.0 aA
SUL	96.5 aA	100.0 aA	97.5 aA	100.0 aA	100.0 aA
SUL + Diuron	90.2 aA	100.0 aA	100.0 aA	100.0 aA	99.7 aA
PYR + FLU	100.0 aA	99.2 aA	100.0 aA	99.7 aA	100.0 aA
CV (%)			6.7		
Control of other weed species at 14 DAA					
Without herbicide	0.0 dB	95.7 abA	99.2 aA	97.7 aA	99.5 aA
S-metolachlor	75.0 cC	87.5 bB	100.0 aA	97.5 aA	100.0 aA
Diclosulam	94.5 abA	99.2 aA	100.0 aA	100.0 aA	100.0 aA
SUL	93.2 abA	100.0 aA	100.0 aA	100.0 aA	100.0 aA
SUL + Diuron	89.2 bB	100.0 aA	100.0 aA	100.0 aA	100.0 aA
PYR + FLU	99.7 aA	100.0 aA	100.0 aA	100.0 aA	100.0 aA
CV (%)			4.5		
Control of other weed species at 34 DAA					
Without herbicide	0.0 dB	80.0 bA	85.5 bA	79.5 bA	84.5 cA
S-metolachlor	61.2 cB	87.2 abA	89.2 abA	88.7 abA	85.7 bcA
Diclosulam	84.2 bB	98.2 aA	98.7 aA	99.5 aA	99.0 aA
SUL	84.5 bB	97.2 aA	98.0 aA	98.2 aA	98.0 abA
SUL + Diuron	84.5 bB	96.0 aAB	97.7 abA	97.7 aA	98.2 abA
PYR + FLU	98.2 aA	98.5 aA	97.5 abA	99.2 aA	98.5 abA
CV (%)			7.16		
Control of other weed species at 111 DAA (Pre -harvest)					
Without herbicide	0.0 bB	33.7 cA	32.0 cA	31.7 bA	32.5 bA
S-metolachlor	16.2 bC	55.0 bAB	67.5 bA	50.7 bAB	47.0 bB
Diclosulam	98.7 aA	99.7 aA	99.5 aA	100.0 aA	99.5 aA
SUL	88.5 aA	99.2 aA	99.2 aA	99.7 aA	98.0 aA
SUL + Diuron	95.0 aA	91.2 aA	96.0 aA	96.7 aA	98.2 aA
PYR + FLU	87.5 aA	88.0 aA	91.7 aA	95.5 aA	96.2 aA
CV (%)			13.5		

Means followed by the same lowercase letter in the columns (Pre-emergence) or uppercase letter in the rows (Post-emergence) are not significantly different from each other by the Tukey's test ($p > 0.05$). SUL - Sulfentrazone, PYR - Pyroxasulfone, FLU - Flumioxazin, G930 - Glyphosate at 930 g a.e. ha^{-1}, G1550 - Glyphosate at 1,550 g a.e. ha^{-1}, and C - Clethodim

less effective against barnyard grass, the dominant species in these treatments. This limited effectiveness against barnyard grass affected the overall control, resulting in a mean of over 90% control of other weeds. Low efficacy of S-metolachlor in controlling *Bidens pilosa* was also reported by Brighenti (2019).

Plant heights was reduced only in the control treatment, in which there was no weed control (Table 4). The herbicides used had no effect on 1000-grain weight, presenting no significant difference among treatments; the untreated control showed no defect-free grains, resulting in zero weight for one thousand grains (Table 4). The number of pods per plant was stable in most treatments. Regarding post-emergence treatments, the glyphosate + clethodim combination presented significantly different results compared to the control without herbicide, with a higher mean number of pods per plant than that found with the application of glyphosate alone (Table 4). The application of sulfentrazone + diuron was the only pre-emergence treatment that resulted in relative decreases in pods per plant above 40% (Table 4).

The high weed infestation hindered the harvest in the control; thus, grain yield was not assessed in this treatment (Table 4). Considering the treatments with only pre-emergence application, the lowest mean yield was found when using the herbicides sulfentrazone + diuron, which was lower than 1,956 kg ha^{-1}. Grain yield was similar in the other treatments. Only treatments with sulfentrazone presented grain yield lower than 3,730 kg ha^{-1}, regardless of the combination (Table 4). This result may be due to the persistent phytotoxicity observed in treatments with sulfentrazone. Therefore, complementary research evaluating sulfentrazone application in floodplain soils is needed to validate the selectivity of this rate in this production environment.

The use of pre-emergence herbicides resulted in reductions of 78% or more in barnyard grass density in all plots. The use of the highest glyphosate rate (1,550 g a.e. ha^{-1}) improved the control efficacy (Table 5). Similar result was found by Christoffoleti & López-Ovejero (2003) for the control of ryegrass. However, the combination of glyphosate with

Table 4. Soybean plant height, number of pods per plant, 1000-grain weight, and grain yield at 111 days after post-emergence application (DAA) of herbicides (pre-harvest)

Pre-emergence	Post-emergence				
	Without herbicide	G930	G1550	G930 + C	G1550 + C
	Plant heights (cm)				
Without herbicide	93.8 bB	124.3 aA	122.9 aA	122.0 aA	125.1 aA
S-metolachlor	123.2 aA	127.5 aA	125.6 aA	123.8 aA	129.3 aA
Diclosulam	127.7 aA	125.0 aA	126.7 aA	115.8 aA	130.6 aA
SUL	116.9 aA	118.4 aA	122.5 aA	120.0 aA	122.7 aA
SUL + Diuron	127.7 aA	117.2 aA	119.3 aA	126.5 aA	128.4 aA
PYR + FLU	113.0 abA	118.6 aA	123.1 aA	117.4 aA	115.0 aA
CV (%)	8.2				
	Number of pods per plant				
Without herbicide	54.5 cB	81.1 aAB	83.8 aAB	86.0 aA	87.0 aA
S-metolachlor	77.7 abcA	81.0 aA	90.2 aA	86.6 aA	85.8 aA
Diclosulam	87.1 abA	85.5 aA	106.1 aA	83.0 aA	94.0 aA
SUL	89.8 aA	98.3 aA	104.1 aA	97.2 aA	96.6 aA
SUL + Diuron	57.8 bcB	96.3 aA	103.3 aA	86.9 aAB	93.5 aA
PYR + FLU	88.0 abA	90.6 aA	94.9 aA	89.6 aA	73.5 aA
CV (%)	17.6				
	1000-grain weight (g)				
Without herbicide	0.0 bB	127.7 aA	126.1 aA	124.8 aA	128.4 aA
S-metolachlor	117.9 aA	133.4 aA	127.8 aA	118.3 aA	124.0 aA
Diclosulam	127.5 aA	141.7 aA	130.1 aA	128.0 aA	123.5 aA
SUL	119.6 aA	122.0 aA	119.7 aA	118.0 aA	117.5 aA
SUL + Diuron	118.5 aA	125.3 aA	123.7 aA	129.9 aA	134.3 aA
PYR + FLU	122.7 aA	126.5 aA	126.9 aA	114.0 aA	123.3 aA
CV (%)	8.6				
	Grain yield (kg ha^{-1})				
Without herbicide	0 cB	4428 abA	3810 aA	4139 aA	3521 aA
S-metolachlor	3216 aB	4500 aA	4007 aAB	3693 aAB	3925 aAB
Diclosulam	3159 aB	3450 bcAB	4060 aAB	4103 aAB	4136 aA
SUL	3127 aA	3477 bcA	3691 aA	3730 aA	3603 aA
SUL + Diuron	1956 bC	3975 abcAB	3164 aB	4344 aA	4059 aAB
PYR + FLU	3333 aA	3383 cA	4013 aA	3699 aA	4107 aA
CV (%)	13.7				

Means followed by the same lowercase letter in the columns (Pre-emergence) or uppercase letter in the rows (Post-emergence) are not significantly different from each other by the Tukey's test ($p > 0.05$). SUL - Sulfentrazone, PYR - Pyroxasulfone, FLU - Flumioxazin, G930 - Glyphosate at 930 g a.e. ha^{-1}, G1550 - Glyphosate at 1,550 g a.e. ha^{-1}, and C - Clethodim

Table 5. Density of barnyard grass and other weed species (plants m^{-2}) at 34 days after post-emergence application (DAA) of herbicides

Pre-emergence	Post-emergence				
	Without herbicide	G930	G1550	G930 + C	G1550 + C
	Barnyard grass density (plants m^{-2})				
Without herbicide	177.0[1] aA[2]	52.5 aB	29.0 aCB	8.0 aCB	6.5 aC
S-metolachlor	5.5 bA	2.5 bA	3.0 abA	2.0 aA	2.0 aA
Diclosulam	38.5 bA	7.0 bAB	18.5 aAB	3.5 aB	2.5 aB
SUL	2.0 bA	1.5 bA	0.0 bA	2.5 aA	1.0 aA
SUL + Diuron	35.5 bA	9.0 abA	4.0 abA	5.0 aA	11.5 aA
PYR + FLU	13.5 bA	2.0 bA	3.0 abA	2.0 aA	0.0 aA
CV (%)	73.65				
	Density of other weed species (plants m^{-2})				
Without herbicide	219.0 aA	45.5 aB	35.0 aB	56.5 aB	46.0 aB
S-metolachlor	72.0 bA	42.0 aA	37.5 aA	54.5 aA	58.5 aA
Diclosulam	26.5 cbA	13.5 abAB	3.5 bB	1.5 bB	1.5 bB
SUL	24.5 cbA	3.0 bAB	2.0 bB	3.0 bAB	7.5 bAB
SUL + Diuron	20.0 cA	8.5 bA	5.5 abA	6.5 bA	7.0 bA
PYR + FLU	5.0 cA	4.0 bA	6.0 abA	1.5 bA	7.5 bA
CV (%)	46.2 %				

[1] Original data; [2]ANOVA and Tukey's test data transformed to $\sqrt{x + 0.5}$; Means followed by the same lowercase letter in the columns (Pre-emergence) or uppercase letter in the rows (post-emergence) are not significantly different from each other by the Tukey's test ($p > 0.05$). SUL - Sulfentrazone, PYR - Pyroxasulfone, FLU - Flumioxazin, G930 - Glyphosate at 930 g a.e. ha^{-1}, G1550 - Glyphosate at 1,550 g a.e. ha^{-1}, and C - Clethodim

clethodim resulted in a more effective control, even when using glyphosate at the lowest rate (Table 5). A synergistic effect of the glyphosate and clethodim mixture was reported by Oliveira et al. (2022), who found increased efficacy of herbicide combinations in controlling *Digitaria insularis*.

The pre-emergence treatments with diclosulam and sulfentrazone + diuron without post-emergence application presented barnyard grass density higher than 35 plants m^{-2}. Sulfentrazone and S-metolachlor applied alone or combined with post-emergence application stood out for the control of barnyard grass, which showed densities equal to or less than 5.5 plants m^{-2} (Table 5).

Despite the density of other weed species was considerably reduced when using post-emergence applications, the increase in the glyphosate rate, applied alone or combined with clethodim, did not result in significant differences in weed density (Table 5), confirming the ineffectiveness of ACCase-inhibiting herbicides in controlling broadleaf species.

However, pyroxasulfone + flumioxazin, and sulfentrazone + diuron applications presented similar control efficacy, regardless the post-emergence application; pyroxasulfone + flumioxazin stood out for keeping the density of other weed species equal to or less than 7.5 plants m^{-2} (Table 5).

Another important factor was the herbicide's effectiveness to reduce reinfestation from the seed bank in these areas. This analysis showed that treatments with S-metolachlor, diclosulam, and pyroxasulfone + flumioxazin, combined with post-emergence application, prevented the production of barnyard grass seeds. However, barnyard grass weeds produced seeds when using treatments with sulfentrazone and sulfentrazone + diuron, even when combined with post-emergence application (Figure 2). The treatments combined with the highest glyphosate rate (1,550 g a.e. ha^{-1}) + clethodim presented no barnyard grass seed production (Figure 2).

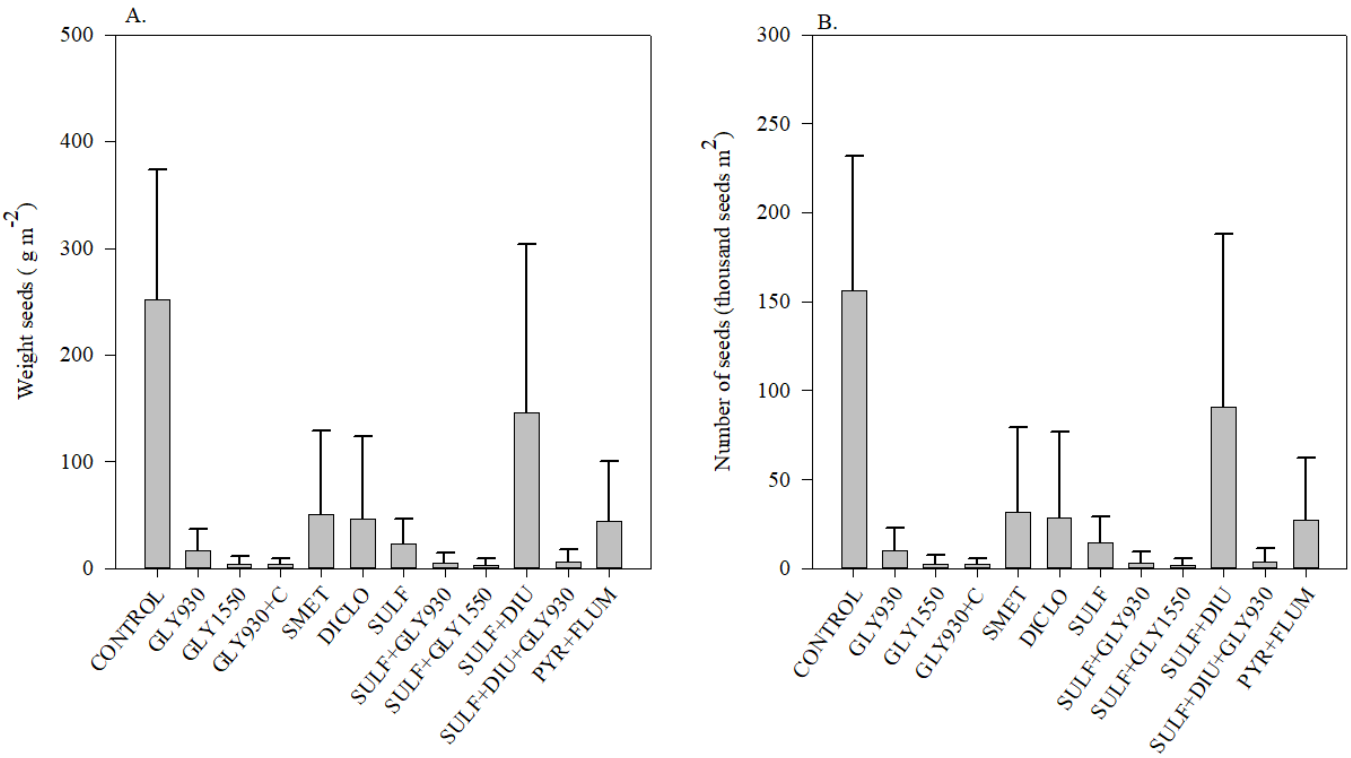
The treatments with exclusive pre-emergence application did not inhibit barnyard grass seed production. The pre-emergence treatment with sulfentrazone + diuron presented barnyard grass seed production similar to the untreated control (Figure 2).

Therefore, the most effective strategy to reduce infestation and the seed bank of barnyard grass in floodplain soils is combining pre- and post-emergence herbicides. Despite the residual effects of some of these herbicides resulted in injuries, symptoms were transient and did not compromise soybean grain yield.

The choice of herbicides for pre-emergence applications should consider the weed species to be controlled and the definition of rates based on soil texture, organic matter, and pH to mitigate problems of lack of selectivity (Pereira et al., 2000; Inoue et al., 2008; Gehrke et al., 2020). Thus, complementary studies evaluating different rates of the herbicides sulfentrazone and sulfentrazone + diuron are recommended for a better adjustment of rates to floodplain soils in southern Santa Catarina.

Table 6 presents the main control parameters evaluated in the present study, summarizing the results of phytotoxicity, barnyard grass control, soybean grain yield, and barnyard grass seed production. These results show that the herbicides S-metolachlor, diclosulam, and pyroxasulfone + flumioxazin caused low phytotoxicity and resulted in a high control of barnyard grass, high grain yield, and suppressed the barnyard grass seed production when combined with post-emergence application.

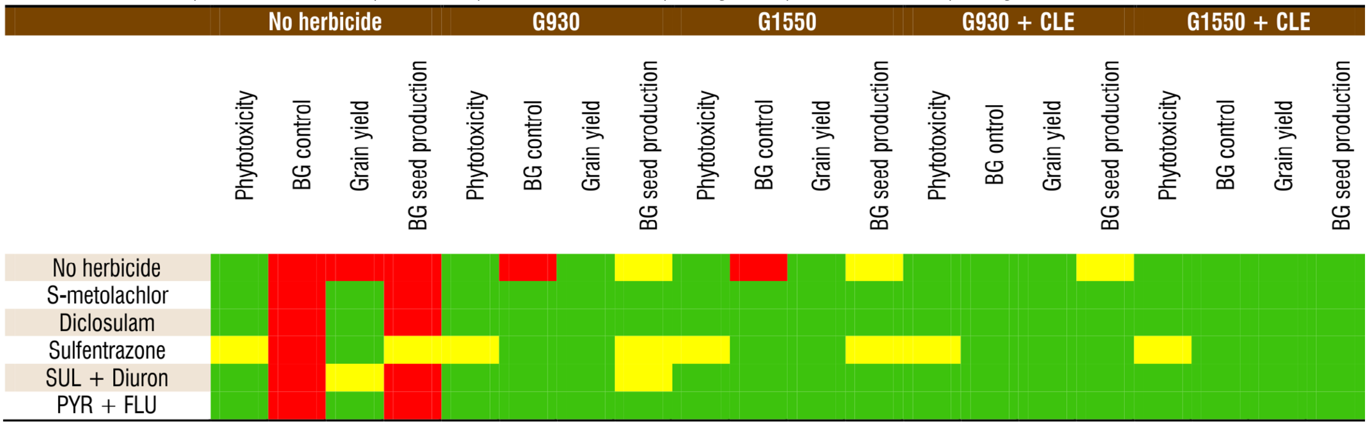
The colors in Table 6 denote the efficiency level for each variable analyzed. Yellow in phytotoxicity indicates treatments that presented injuries higher than 10% at 34 DAA, and green indicates treatments that presented no symptoms in this evaluation. Red in barnyard grass control indicates treatments that presented control lower than 80%, yellow indicates control between 81 and 90%, and green indicates control higher than 91%. Red in the grain yield indicates treatments that were statistically different from the others, with grain yield less than 2,000 kg ha^{-1}; green indicates that the mean grain yield in the other treatments were equal to or more than 3,300 kg ha^{-1}. Red



Vertical lines represent the confidence interval (p ≤ 0.05) Control – Without herbicide, GLY 930 - Glyphosate at 930 g a.e. ha^{-1}, GLY1550 - Glyphosate at 1,550 g a.e. ha^{-1}, C – Clethodim, SMET - S-metolachlor, DICLO - Diclosulam SULF - Sulfentrazone, DIU – Diuron, PYR - Pyroxasulfone, FLU – Flumioxazin

Figure 2. Seed weight (A) and number of seeds (B) of barnyard grass. Only treatments that resulted in barnyard grass seed production were considered

Table 6. Summary of results of phytotoxicity, control of barnyard grass, yield, and barnyard grass seed production



BG – Barnyard grass, SUL - Sulfentrazone, PYR - Pyroxasulfone, FLU - Flumioxazin, G930 - Glyphosate at 930 g a.e. ha^{-1}, G1550 - Glyphosate at 1,550 g a.e. ha^{-1}, and C – Clethodim

in barnyard grass seed production indicates treatments that presented more than 50,000 seeds m^{-2}, yellow indicates a seed production less than 50,000 seeds m^{-2}, whereas green indicates treatments that resulted in no barnyard grass seed production. All these assessments were carried out at 111 DAA.

Thus, the main results of the present study were summarized, denoting the importance of using soybean crops and combinations of pre- and post-emergence herbicides to control barnyard grass and reduce the soil seed bank; additionally, maintaining effective weed control throughout the growing season is essential for soybean crops to reach their yield potential.

Conclusions

1. The herbicide sulfentrazone caused persistent phytotoxicity and resulted in the lowest soybean grain yield.

2. The herbicide S-metolachlor was ineffective in controlling weed species, except barnyard grass, even when combined with post-emergence application.

3. Ineffective weed control results in significant interference, causing significant decreases in grain yield for soybean crops grown in floodplain soils.

4. The use of S-metolachlor, diclosulam, and pyroxasulfone + flumioxazin, combined with post-emergence application of glyphosate (930 g a.e. ha^{-1}), resulted in highly effective barnyard grass control, inhibiting weed seed production.

5. Only the combination of glyphosate (1,550 g a.e. ha^{-1}) with clethodim can suppress the barnyard grass seed production, without using pre-emergence herbicides.

Literature Cited

Agostineto, D.; Fraga, D. S.; Vargas, L.; Oliveira, A. C. B.; Andres, A.; Villela, F. A. Response of soybean cultivars in rotation with irrigated rice crops cultivated in Clearfield® system. Planta Daninha, v.36, e018170991, 2018. https://doi.org/10.1590/S0100-83582018360100048

Alencar, E. S.; Geist, M. L.; Pereira, J. P. M.; Schedenffeldt, B. F.; Nunes, F. A.; Silva, P. V.; Dupas, E.; Mauad, M.; Monquero, P. A.; Medeiros, E. S. Seletividade de herbicidas pós-emergentes isolados ou associados a fertilizante foliar na cultura da soja. Revista de Ciências Agroveterinárias, v.21, p.384-394, 2022. https://doi.org/10.5965/223811712142022384

Arruda, J. S.; Lopes, N. F.; Bacarin, M. A. Crescimento de plantas de soja em função de doses de sulfentrazone. Planta Daninha, v.17, p.375-386, 1999. https://doi.org/10.1590/S0100-83581999000300006

Avila, L. A.; Marchesan, E.; Camargo, E. R.; Merotto, A.; Ulguim, A. R.; Noldin, J. A.; Andres, A.; Mariot, C. H. P.; Agostinetto, D.; Dornelles, S. H. B.; Markus, C. Eighteen years of Clearfield™ rice in Brazil: what have we learned? Weed Science, v.69, p.585-97, 2021. https://doi.org/10.1017/wsc.2021.49

Back, Á. J. Informações climáticas e hidrológicas dos municípios catarinenses (com programa HidroClimaSC). Florianópolis: Epagri, 2020. 157p.

Brighenti, A. M. Controle de *Bidens pilosa* L. (Asteraceae) em girassol com herbicidas residuais. Comunicata Scientiae, v.10, p.293-300, 2019. https://doi.org/10.14295/cs.v10i2.2942

Christoffoleti, P. J.; López-Ovejero, R. Principais aspectos da resistência de plantas daninhas ao herbicida glyphosate. Planta Daninha, v.21 p.507-515, 2003. https://doi.org/10.1590/S0100-83582003000300020

Concenço, G.; Andres, A.; Silva, L. B. X.; Melo, T.S.; Campos, A. D. S.; Sinnemann, C. S. Carryover of [imazapic + imazapyr] on differents crops systems in lowland areas with Clearfield® rice. Revista Brasileira de Ciências Agrárias, v.17, e2127, 2022. https://doi.org/10.5039/agraria.v17i3a2127

Freitas, K.; Bisognin, J.; Furlan, A. E.; Halberstadt, C.; Streck, E. Herbicidas pré-emergentes no controle de capim arroz e ciperáceas na cultura da soja de terras baixas. Enciclopedia Biosfera, v.19, p.1-9, 2022.

Freitas, M. A. M.; Passos, A. B. R. J.; Torres, L. G.; Moraes, H. M. F.; Faustino, L. A.; Rocha, P. R. R.; Silva, A. A. Sorção do sulfentrazone em diferentes tipos de solo determinada por bioensaios. Planta Daninha, v.32, p.385-392, 2014. https://doi.org/10.1590/S0100-83582014000200016

Gehrke, V. R.; Camargo, E. R.; Avila, L. A. Sulfentrazone: Environmental dynamics and selectivity. Planta Daninha, v.38, p.1-16, 2020. https://doi.org/10.1590/S0100-83582020380100032

Gubani, J. E.; Polito, R. A.; Ribas, J. L.; Bagnara, F.; Hahn, A. M.; Cinelli, R.; Heck, T.; Nunes, A. L. Seletividade e controle de plantas daninhas da mistura formulada de sulfentrazone + diuron na cultura da soja / Selectivity and weed control from the formulated mixture of sulfentrazone + diuron in soybean. Brazilian Journal of Development, v.7, p.63320-63333, 2021. https://doi.org/10.34117/bjdv7n6-623

Hay, M. M.; Shoup, D. E.; Peterson, D. E. Herbicide options for control of Palmer amaranth (*Amaranthus palmeri*) and common waterhemp (*Amaranthus rudis*) in double-crop soybean. Weed Technology, v.33, p.106-114, 2019. https://doi.org/10.1017/wet.2018.86

Inoue, M. H.; Oliveira Jr., R. S.; Constantin, J. Alonso, D. G. Santana, D. C. Lixiviação e degradação de diuron em dois solos de textura contrastante. Acta Scientiarum. Agronomy, v.30, p.631-638, 2008. https://doi.org/10.1590/S1807-86212008000500005

Kaspary, T. E.; Burgos N. R., Merotto JR, A. Snorkeling strategy: tolerance to flooding in rice and potential application for weed management. Genes, v.11, p.1-13, 2020. https://doi.org/10.3390/genes11090975

Marchezan, E. Arroz vermelho: caracterização, prejuízo e controle. Ciência Rural, v.24, p.415-421, 1994. https://doi.org/10.1590/S0103-84781994000200036

Oliveira, G. M. P.; Silva, M. A. A.; Dalazen, G. ACCase inhibitor fractionation and glyphosate addition improve perennial sourgrass control. Semina: Ciências Agrárias, v.43, p.657-674, 2022. https://doi.org/10.5433/1679-0359.2022v43n2p657

Pereira, F. A. R.; Alvarenga, S. L. A.; Otubo, S.; Reinaldo, A. M.; Bazoni, R. Seletividade de sulfentrazone em cultivares de soja e efeitos residuais sobre culturas sucessivas, em solos de cerrado. Revista Brasileira de Herbicidas, v.1, p.219-224, 2000. https://doi.org/10.7824/rbh.v1i3.338

Rubin, R. S.; Agostineto, D.; Manica-Berto, R.; Fraga, D. S.; Tarouco, C.P. Resistência de biótipos de arroz-vermelho aos herbicidas imazapyr + imazapic e alternativas de controle. Revista Ceres, v.61, p.660-667, 2014. https://doi.org/10.1590/0034-737X201461050009

Sanchotene, D. M.; Dornelles, S. H. B.; Bolzan, T. M.; Voss, H. M. G.; Escobar, O. S.; Leon, C. B.; Muller, E. N.; Shimóia, E. P. Desempenho de diferentes herbicidas pré-emergentes para controle de *Euphorbia htererophylla* na cultura da soja. Perspectiva Erechim, v.41, p.7-15, 2016.

Santos, H. G.; Jacomine, P. K. T.; Anjos, L. H. C.; Oliveira, V. A.; Oliveira, J. B.; Coelho, M. R.; Lumbreras, J. F.; Cunha, T. J. F. Sistema brasileiro de classificação de solos. 5.ed. Brasília: Embrapa, 2018. 356p.

SBCS - Sociedade Brasileira de Ciência do Solo. Manual de calagem e adubação para os Estados do Rio Grande do Sul e Santa Catarina. Santa Maria: Palloti, 2016. 376p.

Soil Survey Staff. Keys to soil taxonomy, 12.ed, Lincoln: Natural Resources Conservation Service/USDA, 2014. 410p.

Taylor-Lovell, S.; Wax, L. M.; Nelson, R. Phytotoxic response and yield of soybean (*Glycine max*) varieties treated with sulfentrazone or flumioxazin. Weed Technology, v.15, p.95-102, 2001. https://doi.org/10.1614/0890-037X(2001)015[0095:PRAYOS]2.0.CO;2

Vargas, A. A. M.; Agostinetto, D.; Carlos, F. S.; Cereza, T. V.; Ulguim, A. R. Survival and distribution of weedy rice seedbank after twenty-two years of different rice cropping systems. Ciência Rural, v.53, e20210787, 2023. https://doi.org/10.1590/0103-8478cr20210787