PRE-EMERGENT HERBICIDES DURING THE OFF-SEASON OF IRRIGATED RICE: CROP INJURY AND WEEDY RICE CONTROL

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Introduction

Weedy rice (*Oryza sativa* L.) is one of the main weeds in irrigated rice fields in the southern region of Brazil (FRUET et al., 2019), and it can compromise yield losses if left uncontrolled. As the same species, weedy rice competes with cultivated rice for water, light, and nutrients, and the environmental conditions (soil and climatic) that favor cultivated rice generally also favor weedy rice. Currently, one of the main methods of weedy rice control is the use of mutant cultivars with herbicide tolerance, such as inhibitors of acetyl coenzyme-A carboxylase (ACCase) or the group of imidazolinones, with the latter defined as the Clearfield® System (CL).

Clearfield technology is employed in over 80% of the rice-growing area in the Brazil (KALSING et al., 2019). However, with the high frequency of use and sometimes inadequate management, biotypes of weedy rice resistant to imidazolinones have been selected (GOULART et al., 2014). In this regard, managing weedy rice biotypes with resistance is highly relevant, as it is crucial for the success of rice production. In Brazil, genotypes with tolerance to ACCase inhibitor herbicides were released in the 2022/2023 crop season. However, additional management alternatives must be adopted to handle resistant biotypes and mitigate the evolution of resistance to new herbicide action mechanisms.

One of the recommendations for managing resistant weed species is the use of pre-emergence herbicides. This is justified because, in general, these herbicides have mechanisms of action that are distinct from those used post-emergence, and the selection pressure for resistant biotypes to these herbicides is lower (SOMERVILLE et al., 2017). Therefore, an alternative is to apply pre-emergence herbicides that control weedy rice before the rice crop is established. This management alternative is to reduce weedy rice infestation in rice production areas (BERTUCCI et al., 2019). However, injury damage to rice can reach values of 100% (GODWIN et al., 2018), making its application infeasible. Thus, this study analyzed the impact of using pre-emergence herbicides applied during the off-season on weedy rice control and rice injury.

Materials and Methods

An experiment was conducted in the field in a rice yield area in the municipality of Dom Pedrito/RS (latitude 31.01°S and longitude 54.68°W), repeated in the crop seasons 2021/22 and 2022/23. The experimental design used was a randomized complete block design, with four replications, and the experimental units were plots measuring 6 × 15 m (90 m^2) each. The areas had natural infestation of weedy rice (with 3 and 6 plants m^{-2} for the seasons 2021/22 and 2022/23, respectively), and soybean cultivation occurred in the previous seasons.

For the 2021/22 season, the XP202FP hybrid, which is tolerant to herbicides from the imizadolinone chemical group (ALS inhibitors), was used. It was sown on September 23, 2021, at a density of 50 kg ha^{-1}. For the 2022/23 season, the XP739FP hybrid, which also tolerates ALS inhibitor herbicides, was used. It was sown on September 27, 2022, at a density of 45 kg ha^{-1}. Weed management was carried out by applying glyphosate (1440 g ai ha^{-1} in the 2021/22

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season and 1250 g ai ha^{-1} in the 2022/23 season) plus clomazone (360 g ai ha^{-1}) at the rice spiking stage (stage S3) on September 30, 2021, and October 5, 2022, for the first and second crops, respectively. Subsequently, the post-emergence application of florpyrauxifen-benzyl (23.9 g ai ha^{-1}) associated with cyhalofop-butyl (360 g ai ha^{-1}) was conducted at 25 and 26 days after crop emergence (DAE) for the first and second crops, respectively. The start of flooding irrigation occurred at 26 and 27 DAE for the first and second crops, respectively. Other cultural practices followed technical recommendations for rice cultivation.

The experimental treatments were arranged in a factorial design, in which factor A consisted of different times of pre-emergence herbicide application, denoted as “June,” “July,” and “August.” Factor B was the application of the herbicides s-metolachlor (1440 g ai ha^{-1}), flumioxazin (50 g ai ha^{-1}), pyroxasulfone (170 g ai ha^{-1}), sulfentrazone + diuron (210 g and 420 g ai ha^{-1}, respectively), and the control (no herbicide). The times were named June, July, and August to facilitate the presentation of results, referring to applications made 100, 78, and 47 days before rice sowing, respectively, for the 2021/22 season and 42, 26, and 10 days before rice sowing, respectively, for the 2022/23 season. Treatment applications were carried out using a pressurized backpack sprayer with CO_2, equipped with 110,015 flat fan nozzles, at a spray volume of 150 L ha^{-1}.

The variables assessed included the control (%) of weedy rice and crop injury (%) conducted at 36, 54, and 75 days after sowing (DAS), respectively, for the 2021/22 harvests and 33, 51, and 70 DAS for the 2022/23 harvests, respectively. Additionally, the control of weedy rice pre-harvest was evaluated using the percentage scale, in which 0 indicates no damage and 100 indicates plant death. The data obtained underwent analysis of variance (ANOVA) ($p \leq 0.05$), and in cases of significant differences, the Scott–Knott mean test ($p \leq 0.05$) was employed.

Results and Discussion

For de growing season 2021/2022, the efficiency in controlling weedy rice throughout the crop cycle with the use of pre-emergent herbicides was not observed when assessed at 54 and 148 DAS (Table 1). Injury values did not exceed 14% under any condition, indicating that flumioxazin and sulfentrazone + diuron caused greater damage to rice compared to other treatments at 75 DAS (Table 1). An interaction between the time of application and the herbicides used was observed for the variables of control at 36 and 75 DAS and injury at 36 DAS (Table 2).

Table 1- Control of weedy rice and injury (%) of rice crop according to the application timings and herbicides applied in off-season management. Dom Pedrito, RS, 2021/2022.

Application timings/Herbicides	Control (%)		Injury (%)	
	54 DAS[1]	148 DAS	54 DAS	75 DAS
Application timings				
June (Jun)	0 a[2]	0 b	4 b	7 b
July (Jul)	0 a	0 b	4 b	6 b
August (Aug)	0 a	1 a	8 a	12 a
Herbicides				
Control	0 b	0 a	0 b	0 c
S-metolachlor	1 a	0 a	7 a	9 b
Sulfentrazone + diuron	1 a	1 a	8 a	12 a
Pyroxasulfone	0 b	0 a	5 a	6 b
Flumioxazin	0 b	0 a	7 a	14 a
CV (%)	24.5	21.5	31.1	29.0

[1] Days after sowing. [2] Averages followed by the same letter do not differ significantly by the Scott–Knot test at 5% probability.

The control provided by s-metolachlor and sulfentrazone + diuron was generally superior to the others, regardless of the application timing (Table 2). For these herbicides, the application had the greatest effect, approaching or reaching close to 10% for application in August and evaluation at 36 DAS. Overall, the application in August led to an increase in the control variable for all herbicides tested. However, applications in August resulted in greater injury to rice at 36 DAS, with rates of 14, 20, and 12% for herbicides s-metolachlor, sulfentrazone + diuron, and flumioxazin, respectively. The sulfentrazone + diuron herbicide differed from the non-application control in all seasons regarding the variable of injury at 36 DAS. However, the pyroxasulfone herbicide differed only from the control in terms of injury at this evaluation time in July, but its effect was inferior to the others (Table 2).

Table 2- Control of weedy rice and injury (%) of rice crop according to the application timings and herbicides applied in off-season management. Dom Pedrito, RS, 2021/22.

Application timings/ Herbicides	Control (%)						Injury (%)		
	36 DAS[1]			75 DAS			36 DAS		
	Jun	Jul	Aug	Jun	Jul	Aug	Jun	Jul	Aug
Control	0 Ba[2]	0 Ca	0 Ca	0 Aa	0 Aa	0 Ba	0 Da	0 Ca	0 Da
S-metolachlor	1 Bb	6 Aa	9 Aa	0 Ab	0 Ab	4 Aa	8 Bb	6 Ab	14 Ba
Sulfentrazone + diuron	5 Ab	8 Aa	10 Aa	0 Ab	0 Ab	5 Aa	15 Aa	8 Ab	20 Aa
Pyroxasulfone	0 Bb	1 Cb	4 Ba	0 Aa	0 Aa	1 Ba	5 Ca	3 Ba	6 Ca
Flumioxazin	0 Bb	3 Ba	5 Ba	0 Ab	0 Ab	3 Aa	10 Ba	7 Ab	12 Ba
CV (%)	25.3			20.9			15.2		

[1] Days after sowing. [2] Capital letters compare treatments in the same timing (columns), and lowercase letters compare treatments between timings (rows). Averages followed by the same letter do not differ significantly by the Scott–Knot test at 5% probability.

For the growing season 2022/2023 and the time application factor, the best control performance occurred in the third application time (August), but with values below 2%. Concerning the herbicide factor, the best performances in the rice pre-harvest evaluation were observed with s-metolachlor and sulfentrazone + diuron, with 2 and 3%, respectively. Similarly, the highest levels of injury to the crop occurred during the application carried out in August, reaching 13%, which differed from other times. For herbicides, the highest values were recorded for s-metolachlor, sulfentrazone + diuron, and flumioxazin at both evaluation times (51 and 70 DAS) (Table 3).

Table 3- Control and injury (%) of rice crop according to the application timings and herbicides applied in off-season management. Dom Pedrito, RS, 2022/23.

Application timings/ Herbicides	Control (%)		Injury (%)	
	51 DAS[1]	146 DAS	51 DAS	70 DAS
Application timings				
June	1 b[2]	0 b	6 b	10 b
July	2 b	1 b	7 b	11 b
August	4 a	2 a	13 a	14 a
Herbicides				
Control	0 c	0 b	0 d	0 c
S-metolachlor	7 a	3 a	11 b	15 a
Sulfentrazone + diuron	5 b	2 a	15 a	18 a
Pyroxasulfone	1 c	1 b	5 c	7 b
Flumioxazin	0 c	0 b	11 b	18 a
CV (%)	26.2	42.7	43.4	36.5

[1] Days after sowing. [2] Means followed by the same letter do not differ significantly according to the Scott–Knott test at 5% probability.

When analyzing the percentage of control at 33 and 70 days after sowing (DAS) and injury at 33 DAS, a significant interaction between the factors was observed (Table 4). The highest control values were achieved in August for all herbicides in both evaluations (33 and 70 DAS). Herbicides, such as s-metolachlor and sulfentrazone + diuron, exhibited the best performance regardless of the application timing, reaching peak values during the August application, with 24 and 14%, respectively, at 33 DAS (Table 4). Regarding injury values, the herbicides s-metolachlor, sulfentrazone + diuron, and flumioxazin exhibited injury values greater than 10% at all application times. This effect was most pronounced in August, in which values approached or exceeded 30%, differing significantly from other treatments. Conversely, pyroxasulfone demonstrated injury values lower than 8%, indicating a higher level of selectivity for the crop at the tested dosage (Table 4).

Table 4- Control (%) of weedy rice and crop injury (%) of rice crops according to the application timings and herbicides applied in off-season management. Dom Pedrito, RS, 2022/23.

Application timings Herbicides	Control (%)						Injury (%)		
	33 DAS[1]			70 DAS			33 DAS		
	June	July	August	June	July	August	June	July	August
Control	0 Ba[2]	0 Ba	0 Da	0 Aa	0 Ba	0 Ba	0 Ba	0 Ca	0 Da
S-metolachlor	4 Ac	9 Ab	24 Aa	2 Ac	5 Ab	9 Aa	11 Ab	14 Ab	29 Ba
Sulfentrazone + diuron	3 Ac	6 Ab	14 Ba	0 Ab	0 Bb	6 Aa	15 Ab	15 Ab	34 Aa
Piroxasulfone	0 Bb	3 Ba	5 Ca	0 Aa	0 Ba	1 Ba	4 Ba	6 Ba	8 Ca
Flumioxazin	0 Bb	3 Ba	5 Ca	0 Ab	0 Bb	3 Ba	10 Ab	13 Ab	35 Aa
CV (%)	29.5			31.7			28.9		

[1] Days after sowing. [2] Capital letters compare treatments within the same timing (columns), and lowercase letters compare treatments across timings (rows). Means followed by the same letter do not differ significantly according to the Scott–Knott test at 5% probability.

Conclusion

The use of herbicides s-metolachlor (1440 g ai ha^{-1}), sulfentrazone + diuron (210 + 420 g ai ha^{-1}), pyroxasulfone (170 g ai ha^{-1}), and flumioxazin (50 g ai ha^{-1}) applied before rice sowing did not control more than 24% of weedy rice in rice crops. The herbicides s-metolachlor (1440 g ai ha^{-1}) and sulfentrazone + diuron (210 + 420 g ai ha^{-1}) when applied at intervals of up to 26 days before sowing the crop caused low injury without significantly affecting crop yield.

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