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BARNYARDGRASS CONTROL BY DIFFERENT HERBICIDES IN RICE CROPS LOCATED IN THE EXTREME SOUTHERN STATE OF SANTA CATARINA

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ABSTRACT: Barnyardgrass (*Echinochloa* spp.) is one of the main weeds in irrigated rice, as it is difficult to control due to morphophysiological similarities with the crop and aggravation of the problem of resistance to herbicides registered for the management of the species. In order to find alternatives for the management of this weed, this study was developed with the objective of evaluating the control of barnyardgrass resulting from the use of different herbicides applied after rice emergence, as well as their effect on the productivity of rice fields located in the extreme southern state of Santa Catarina. A field experiment was implemented in the 2020/2021 season in a randomized block experimental design with four replicates. Treatments were: florpyrauxifen-benzyl (30 g active ingredient ha^{-1}), imazapyr + imazapic (105 + 35 g a.i. ha^{-1}) and fenoxaprop-p-ethyl (82,8 g a.i. ha^{-1}), in addition to control without herbicide application. Variables analyzed were: weed control (%) and crop phytotoxicity (%), evaluated at 12 and 40 days after application (DAA); and crop productivity (kg ha^{-1}) at stage R9. Based on results obtained, it could be concluded that the evaluated herbicides were efficient in the barnyardgrass management and, in general, were selective to the crop, resulting in improvement in grain yield, since the presence of weeds negatively interfered with the productive performance of irrigated rice.

KEYWORDS: *Echinochloa* spp., chemical management, *Oryza sativa*, pre-germinated.

CONTROLE DE CANEVÃO POR DIFERENTES HERBICIDAS EM LAVOURA DO EXTREMO SUL CATARINENSE

RESUMO: O canevão (*Echinochloa* spp.) é uma das principais plantas daninhas do arroz irrigado, devido à dificuldade de controle decorrente das semelhanças morfofisiológicas com a cultura e agravamento do problema de resistência aos herbicidas registrados para o manejo da espécie. Com intuito de buscar alternativas para o manejo dessa planta daninha, foi desenvolvido estudo com o objetivo de avaliar o controle de canevão resultante da utilização de diferentes herbicidas aplicados em pós-emergência, bem como efeito desses sobre a produtividade em lavoura de arroz do Extremo Sul Catarinense. Experimento a campo foi implantado na safra 2020/2021 em delineamento experimental em blocos casualizados com quatro repetições. Os tratamentos foram: florpyrauxifen-benzyl (30 g ingrediente ativo ha^{-1}), imazapyr + imazapic (105 + 35 g i.a. ha^{-1}) e fenoxaprope-p-etílico (82,8 g i.a. ha^{-1}), além da testemunha sem aplicação. As variáveis foram: controle da planta daninha (%) e fitotoxicidade na cultura (%), avaliadas aos 12 e 40 dias após aplicação (DAA); e produtividade (kg ha^{-1}) na cultura, no estádio R9. A partir dos resultados, conclui-se que os herbicidas avaliados foram eficientes no manejo do canevão e, em geral, seletivos a cultura, resultando na melhoria da produtividade de grãos, uma vez que a presença de plantas daninhas interferiu negativamente para o desempenho produtivo do arroz irrigado.

PALAVRAS CHAVE: *Echinochloa* spp., manejo químico, *Oryza sativa*, pré-germinado.

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INTRODUCTION

Rice (*Oryza sativa* L.) cultivation is an activity with world production of 755 million tons in a cultivated area of 162 million hectares (Faostat, 2019). China is the largest producer (139 million tons), followed by India (118 million tons) and Indonesia (36 million tons). Brazil occupies the twelfth position, with production of 11.7 million tons in an area of 1.6 million hectares (Conab, 2021).

Although Brazil holds a prominent position in the global rice farming scenario, the productivity level considered ideal for the crop has not yet been reached due to several factors that need to be improved, such as water management, fertility, seed quality, systematization of floodplains and phytosanitary management. Among factors that have direct interference in the rice production process, the presence of weeds, mainly liliopsida, stands out due to competition with the crop for water, light and nutrients.

Among liliopsida that cause damage to rice crops, *Echinochloa* spp. (barnyardgrass) is one of the main due to its morphophysiological characteristics similar to crop itself (Galon et al., 2009). Study conducted by VanDevender et al. (1997) demonstrated that 20 barnyardgrass plants m^{-2} can reduce rice productivity by up to 80%. In the State of Rio Grande do Sul (RS), several studies have quantified the direct loss in productivity of irrigated rice grains, due to competition with barnyardgrass plants. Each barnyardgrass plant per square meter reduces productivity by an average of 64 kg ha^{-1} (Andres and Menezes, 1997). Other studies have demonstrated that productivity losses can vary between 4 and 85% depending on weed population, cultivar used and the times of water entry into the crop (Galon et al. 2007a, b; Agostinetto et al. 2007).

Barnyardgrass has annual cycle, adaptation to anaerobic conditions, rapid biomass accumulation, provided by its greater photosynthetic efficiency, as it has C4 metabolism and large seed production (Kissman and Groth, 1997), around 35,500 seeds per plant (Bagavathiannan et al., 2012), which replenishes the soil seedbank, perpetuating infestation in rice-growing areas.

In addition to rapid growth, barnyardgrass can make harvesting difficult due to the lodging of rice plants and can serve as intermediate host for insect pests and diseases (Haber and Harder, 1992; Maziero et al., 2007). The aforementioned characteristics associated with the presence of biotypes resistant to certain herbicides, such as *Echinochloa crus-galli* to herbicides that inhibit the acetolactate synthase - ALS enzyme (bispyribac-sodium, imazethapyr and penoxsulam) and auxin mimetic (quinclorac) (Heap, 2021) make management difficult and increase the importance of the species as a weed. In fact, this is a scenario that has been aggravated by the emergence of biotypes with multiple resistance to three mechanisms of action: ALS, ACCase and synthetic auxin inhibitors (Heap, 2021).

In an attempt to seek efficient management alternatives, this study was developed with the aim of evaluating the control of barnyardgrass resulting from the use of different herbicides applied after rice emergence, as well as their effect on productivity in rice crops located in the extreme southern state of Santa Catarina.

MATERIAL AND METHODS

The experiment was carried out in the 2020/2021 agricultural season in an irrigated rice field located in the Extreme Southern State of Santa Catarina (28°47'33.8"S and 49°43'28.1"W). According to the Köppen-Geiger classification, the local climate is Cfa type, humid subtropical, with average annual rainfall of 1,600 mm. Soil preparation was carried out with straw management in the off-season, and at the time of implementation, soil was prepared with rotary hoe to form mud, with subsequent smoothing and leveling of the area, leaving the seeding bed suitable for the pre-germinated system.

Rice was sown by broadcast (150 kg/ha) in water with pre-germinated seeds. The cultivar used in the study was SCS 121 CL, with late cycle, tolerance to lodging and high productive potential (Epagri, 2014), defined by the predominance of use in the extreme southern state of Santa Catarina. Each experimental unit was composed of 4 m x 2 m (8 m^2), leaving 1 m at the ends as border. The experimental design was in randomized blocks with four replicates. Before carrying out the study, soil chemical characteristics were identified (Table 1).

Table 1. Chemical analysis and clay percentage of a Fluvic Cambisol.

Clay %	pH H_2O	SMP	O.M. %	P (mg dm^{-3})	K (mg dm^{-3})	% Base Saturation		
18	5.0	5.3	2.0	3.0	40.0	33.4		
Al $_{exch.}$	Ca $_{exch.}$ (cmol$_c$ dm^{-3})	Mg $_{exch.}$ (cmol$_c$ dm^{-3})	H + Al	CEC	S %	Ratios Ca/Mg	Ratios Ca/K	Ratios Mg/K
2.2	5.1	3.6	9.7	14.6	4.8	2.9	34.9	11.7

pH in water. SMP: pH measured after addition of buffered SMP solution. O.M.: Organic matter = Organic C x 1.724. P, K: Mehlich^{-1} extractor. Ca, Mg and Al: KCl extractor (1 mol L^{-1}). H+Al: calcium acetate extractor (0.5 mol L^{-1}). CEC: cation exchange capacity.

Treatments consisted of different herbicides applied after rice emergence: florpyrauxifen-benzyl (30 g i.a. ha^{-1}), imazapyr + imazapic (105 + 35 g i.a. ha^{-1}) and fenoxaprop-p-ethyl (82.8 g i.a. ha^{-1}), in addition to control without herbicide application. After treatments, 1 day later, irrigation was restarted by entering water into the crop, with water level being periodically controlled through a channel next to the rice field.

Treatments were sprayed after emergence with precision sprayer, displacement speed of 1.0 m s^{-1}, height in relation to the target of 0.5 m and spray volume equivalent to 150 L ha^{-1}. Fertilization was carried out in the following amounts and times: 250 kg of fertilizer formulated at 7-28-14 ratio, 30 days after sowing; and 350 kg of chlorinated urea 40 days after sowing. The other management practices used in the experiment were those recommended for the crop (Eberhardt and Schiocchet, 2015).

Variables under study were: barnyardgrass control (%); phytotoxicity on the rice crop (%); and such evaluations were carried out together at 12 and 40 days after application (DAA), assigning percentage values between 0 (absence of weed control or crop phytotoxicity) and 100% (total weed control or death of crop plants) (SBCPD, 1995).

At the end of the cycle, at stage R9, manual harvesting was carried out to determine the productivity of each treatment in a useful area of 2 m^2 inside the plot, where samples were submitted to threshing and removal of impurities, weight determination on scale and subsequent correction for kg ha^{-1} with 13% humidity.

Data obtained were submitted to analysis of variance and if statistical significance was found, the Tukey test ($p \leq 0.05$) was used to compare treatments.

RESULTS AND DISCUSSION

For variable barnyardgrass control, it was found that all herbicide treatments evaluated were effective for the management of the species, presenting values, in general, above 80% (Table 2). In absolute terms, reduction in the control of the species in the second evaluation period was observed (40 DAA), especially for herbicide imazapyr + imazapic, which justifies the manufacturer's recommendation for two sequential applications (Agrofit, 2021).

Table 2. Barnyardgrass control and phytotoxicity in rice plants, SCS 121 CL cultivar, resulting from different herbicides applied after rice emergence, evaluated at 12 and 40 days after application of treatments (DAA). Agricultural year 2020/2021, Morro Grande/SC.

Treatment	Dose (g a.i. ha^{-1})	Control (%)		Phytotoxicity (%)	
		12 DAA	40 DAA	12 DAA	40 DAA
Control	-	0.00 b[1]	0.00 b	0.00 c	0.00[NS]
Florpyrauxifen-benzyl	30	100.00 a	95.00 a	25.00 b	0.00
Imazapyr + imazapic	105 + 35	94.37 a	80.00 a	8.00 c	0.00
Fenoxaprop-p- ethyl	82.8	95.62 a	91.00 a	37.50 a	0.00
CV (%)		4.14	17.37	21.75	0.00

[1]Averages followed by the same letter in the column do not differ statistically using the Tukey Test ($p \leq 0.05$). NS Not significant at the 5% level by the F test.

The present study indicates the efficiency of treatments in the management of the weed species (Table 2), highlighting that such herbicides present different mechanisms of action (florpyrauxifen-benzyl – auxin mimetic; imazapyr + imazapic – Acetolactate synthase (ALS) inhibitors; fenoxaprop-p-ethyl – Acetyl-CoA Carboxylase (ACCase) inhibitors). Consequently, these products are effective options within a system based on the rotation of active ingredients with the aim of maintaining the viability of the chemical management strategy and prevention of resistance problems.

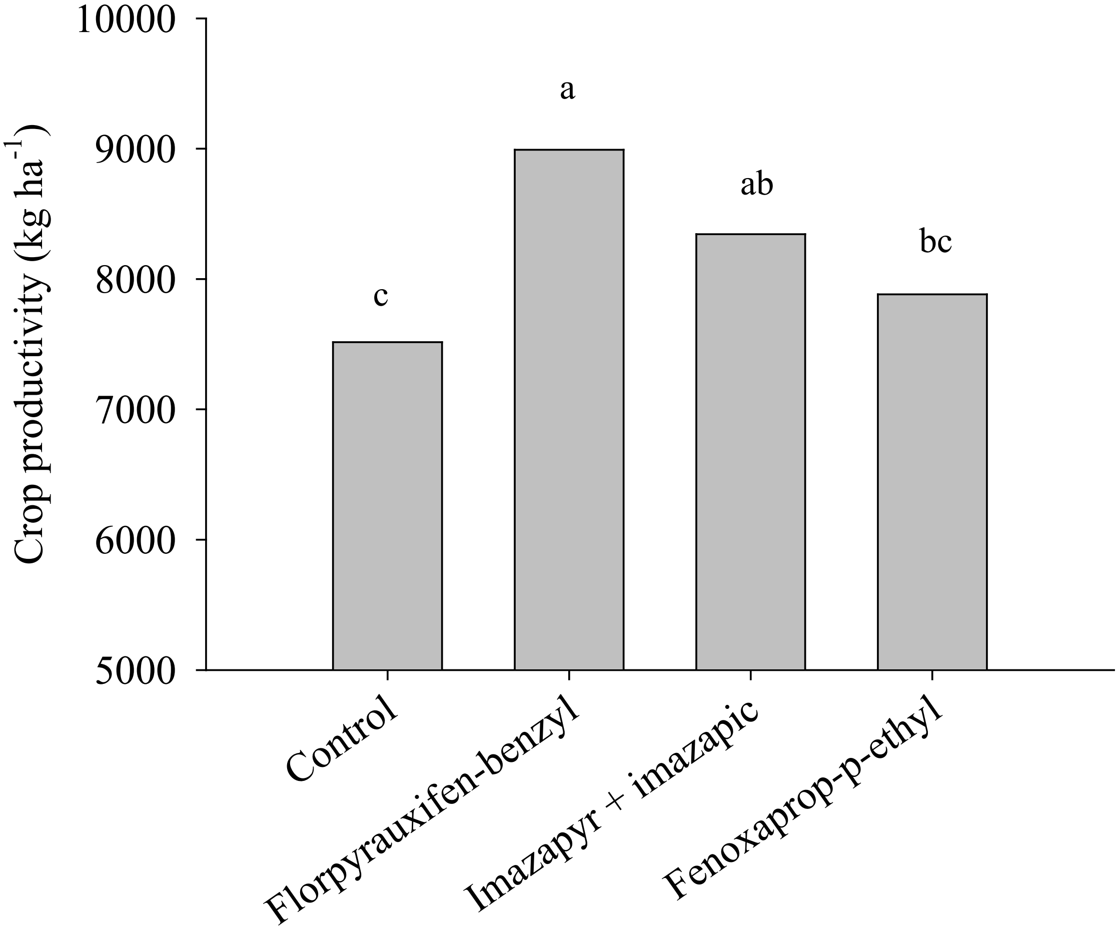
Recently, in the United States, barnyardgrass biotypes resistant to florpyrauxifen-benzyl were identified due to the lower production of the active metabolite of the herbicide in the plant and lower absorption of the product identified for resistant biotypes (Hwang et al., 2021), in addition to cases already recorded of barnyardgrass resistant to ALS and ACCase inhibitors (Heap, 2021), demonstrating the worrying scenario and the importance of prevention measures and rotation of active ingredients with different mechanisms of action in an attempt to limit the expansion of resistant weed species.

Despite the effectiveness in controlling the species resulting from the use of herbicides, it was found that the crop showed signs of phytotoxicity, detected in the first evaluation (12 DAA) (Table 2), with values observed, from greatest injury to least, to fenoxaprop -p-ethyl, florpyrauxifen-benzyl and imazapyr + imazapic, indicating that depending on the active ingredient, there is differentiation in the behavior of initial tolerance of rice plants to herbicides.

When evaluating rice tolerance to herbicide fenoxaprop-p-ethyl, studies have demonstrated that the plant's ability to survive the use of the pesticide is partly explained by the lower sensitivity of the ACCase enzyme in the crop (Bjelk et al., 1991) and gene regulation (Pan et al., 2017); however, injuries can be detected, as there is also record of reduction in the photosynthetic rate and partial inhibition of leaf elongation in plants treated with fenoxaprop-p-ethyl (Oosterhuis et al., 1990). When analyzing the behavior of rice after herbicide application, initial phytotoxic effect of fenoxaprop-p-ethyl was also identified, but the crop has capacity for visual recovery, given the absence of injuries in plants for the second evaluation period (Table 2).

Study carried out by Bundt et al. (2019) with the Guri INTA CL cultivar demonstrated that florpyrauxifen-benzyl was efficient in controlling ALS-resistant barnyardgrass, including maintaining performance in association with clomazone, cyhalofop-butyl and the mixture composed of imazapyr + imazapic; and selectivity to irrigated rice cultivation; however, when evaluating the tolerance of rice crops to herbicide florpyrauxifen-benzyl, Wright et al. (2021) demonstrated that CL272 and CLXL745 cultivars are sensitive to sequential florpyrauxifen-benzyl applications, indicating that the genetic material, as well as the interaction between dose and environment affect the herbicide selectivity. However, although injuries were identified in the first evaluation period after using the herbicide (Table 2), with the advancement of rice development, such events were overcome by the crop, even showing, in absolute terms, the highest productivity values (Figure 1).

Figure 1. Rice productivity, SCS 121 CL cultivar, resulting from barnyardgrass control obtained from different herbicides applied after rice emergence evaluated at stage R9. Variable values corrected for hectare and 13% humidity. Agricultural year 2020/2021, Morro Grande/SC.



When analyzing productivity, direct influence of the interference exerted by weeds on grain productivity is verified, since the control treatment presented lower value for this variable (Figure 1). Such results were already expected and corroborate those obtained by Stauber et al. (1991), who found that barnyardgrass population from 1 to 20 plants m^{-2} also reduced the grain yield of Lemont and Newbonnet cultivars by 201 and 257 kg ha^{-1} per weed, respectively.

Losses in crop productivity are due to reduction in the photosynthetic rate, root biomass production, oxidative activity of roots at the grain filling stage and dry mass accumulation at maturation resulting from the interference in the use of light caused by barnyardgrass (Zhang et al., 2017), and such negative effects are dependent on several factors, such as weed species, also identified by the same authors when they showed that the loss in rice grain yield was 12.7-42.6% in the presence of *Echinochloa crus-galli* var. *mitis*, 22.3-55.2% for *E. crus-galli crusgali* var. *zelayensi*s; and 1.5-12.1% for *E. colonum*.

Florpyrauxifen-benzyl and imazapyr + imazapic treatments achieved higher yields, above 8.3 tons ha^{-1} (Figure 1); while the fenoxaprop-p-ethyl treatment, despite absolute values higher than control, showed no significant difference compared to control treatment, which demonstrates that the initial phytotoxicity detected in the crop possibly influenced grain productivity. It is believed that this behavior is dependent on cultivar, dose and time of application, because when evaluating rice tolerance to the herbicide, Griffin and Baker (1990) found that for the Mars cultivar, reduction of 11 and 23% in grain productivity was observed after using 168 and 336 g a.i. ha^{-1}, respectively, applied before or after flooding; while for Lemont and Tebonnet cultivars, only post-flood herbicide applications reduced crop yields.

Nevertheless, several studies have demonstrated the safety of using the herbicide, such as the work developed by Snipes and Street (1987), who found that doses of 112 and 168 g a.i. ha^{-1} or two applications of 112 g a.i. ha^{-1}, applied with 10 to 14 days of interval, did not affect grain yield. Furthermore, Snipes et al (1987) also detected that rice productivity was not affected by the use of 168 g a.i. ha^{-1} of fenoxaprop-p-ethyl and flooding from 1 to 10 days after herbicide treatment.

Thus, according to results obtained, it could be concluded that herbicides florpyrauxifen-benzyl (30 g a.i. ha^{-1}), imazapyr + imazapic (105 + 35 g a.i. ha^{-1}) and fenoxaprop-p-ethyl (82,8 g a.i. ha^{-1}), applied after rice emergence (SCS 121 CL) were efficient in the barnyardgrass management and, in general, were selective to the crop, resulting in increased grain productivity, since the presence of weeds negatively interfered in the productive performance of irrigated rice.

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