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Research Article

Control of *Echinochloa* sp. in the Irrigated Rice Crop

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The species of *Echinochloa* (barnyardgrass) stand out among major weeds infesting rice cropping and damages are variable depending on the weed population, rice cultivar, and management practices adopted by rice farmers. The objective of this work was to measure the control of barnyardgrass in rice cropping, cultivar Qualimax 1, due to the early times of flood irrigation, application times, and doses of penoxsulam. The experiment was conducted in the field, where the experimental design used a randomized block design with a split plot design with four replications. The treatments consisted of two application periods (early and late) of penoxsulam three times of irrigation start (1, 15 and 30 days after treatment application—(DAT)) and herbicide doses (0, 24, 36, 48 and 60 g ha^{-1}). The herbicide penoxsulam revealed that combined with irrigation starting 15 days after herbicide application promoted efficient control of barnyardgrass.

1. Introduction

The area cultivated with rice in Brazil is estimated at around 2,4 million hectares, with predominance of irrigated rice production with yield of grain average 7133 kg ha^{-1} [1]. The occurrence of weeds in rice fields is a major factor limiting the potential for crop productivity in Brazil, and losses vary according to the plant species, weed population, the rice cultivar, and management practices adopted by rice farmers [2, 3].

The weeds present in rice pads stand out as barnyardgrass (*Echinochloa* spp.), because has similarities morphophysiological with rice plants, wide distribution, and high levels of infestation in crops [4]. Furthermore, there is a high adaptability of this species intraspecific variability due to the large, high potential competition for resources [5, 6], even at low density, which makes its control essential [7].

Among the weeds present in rice pads, regardless of the system of rice cultivation, chemical control is the main alternative for the management of barnyardgrass, because of its efficiency and practicality [8]. However, the use of herbicides should be strategically integrated with other management practices, seeking the agronomic efficiency and cost reduction [9, 10]. Interactions between irrigation season, time of application, and herbicide rate are important to achieve efficient control of weeds in all cropping systems of rice [11].

Currently, there are commercially available 17 herbicides suitable for control of barnyardgrass in Brazil [6]. To obtain an adequate control to prevent and reinfestation, it is necessary that the herbicide has residual effect. The use of herbicides with residual activity in the soil, allows the delay irrigation, because inhibition of germination and emergence of weed that would be exerted by the water are replaced by the action of the herbicide [12]. However, the length of this period depends on the product, the dose, the weed species, and the level of infestation of the soil and climatic conditions, ranging from 15 to 30 days after application, depending on the adopted management [8].

The penoxsulam herbicide is characterized as being selective in rice, controlling various weed species [13] and residual effect in the soil, which prevents the emergence of weeds new flow before establishment of flood irrigation [14].

Table 1: Percentage control *Echinochloa* sp. (barnyardgrass) in irrigated rice, due to periods of flooding, application times, and doses of penoxsulam, Rio Grande, RS, Brazil.

Dose ($g \cdot ha^{-1}$)	Beginning of irrigation	Application time							
		Premature	Late	Premature	Late	Premature	Late	Premature	Late
		10 DAT[1]		20 DAT		30 DAT		81 DAT	65 DAT
0	1 DAT	0 Aa[2]	0 Aa	0 Aa	0 Aa	0 Aa	0 Aa	0 Aa	0 Aa
	15 DAT	0 Aa	0 Aa	0 Aa	0 Aa	0 Aa	0 Aa	0 Aa	0 Aa
	30 DAT	0 Aa	0 Aa	0 Aa	0 Aa	0 Aa	0 Aa	0 Aa	0 Aa
24	1 DAT	98 Aa	78 Ab	100 Aa	88 Ab	100 Aa	98 Aa	100 Aa	98 Aa
	15 DAT	75 Ba	64 Ba	81 Ba	85 Aa	91 Ba	92 Aa	98 ABa	98 Aa
	30 DAT	72 Ba	60 Bb	68 Cb	75 Ba	78 Cb	86 Ba	96 Ba	94 Bb
36	1 DAT	98 Aa	84 Ab	100 Aa	91 Ab	100 Aa	99 Aa	100 Aa	99 Aa
	15 DAT	86 Aa	68 Bb	85 Ba	90 Aa	99 Aa	98 Aa	100 Aa	99 Aa
	30 DAT	88 Aa	71 ABb	86 Ba	83 Aa	91 Ba	94 Aa	98 Aa	96 Ba
48	1 DAT	99 Aa	91 Aa	100 Aa	95 Aa	100 Aa	100 Aa	100 Aa	99 Aa
	15 DAT	88 Aa	71 Bb	93 ABa	92 Aa	99 Aa	98 Aa	100 Aa	99 Aa
	30 DAT	87 Aa	75 Bb	91 Ba	88 Aa	95 Aa	95 Aa	99 Aa	97 Aa
60	1 DAT	99 Aa	93 Aa	100 Aa	96 Aa	100 Aa	100 Aa	100 Aa	100 Aa
	15 DAT	96 Aa	80 Ab	98 Aa	96 Aa	100 Aa	99 Aa	100 Aa	100 Aa
	30 DAT	95 Aa	81 Ab	92 Aa	90 Aa	97 Aa	97 Aa	99 Aa	99 Aa

[1]Days after treatment application.[2]Means followed by the same capital letters in the column in each application time compare times of early irrigation within dose and followed by the same lowercase line, compare application time within herbicide and times start of irrigation, and do not differ by Tukey's test ($P \leq 0,05$).

In this context, the aim of the research was to evaluate the control of barnyardgrass in the irrigated rice cv Qualimax 1, depending on the time of onset of flooding, application times, and doses of penoxsulam.

2. Material and Methods

The experiment was conducted in the field, in the Granja Quatro Irmãos, at Rio Grande, RS, crop year 2005/2006. The soil is classified as Lowland Solodic belonging to Unit Mapping Pelotas. The fertilization was performed according to the analysis of soil using 200 $kg \cdot ha^{-1}$, 5-20-20 formulation at sowing, and 100 kg^{-1} N·ha coverage split applications at the start of tillering and issuance of the primodium leaf (36 and 60 DAE).

The experiment was conducted in a minimum tillage system, and the experiment was a randomized block design with split plots in a factorial design ($2 \times 3 \times 5$) with four replications. Each block was composed of an area of 245 m^2 (98.0 m×2.5 m), plots with an area of 75 m^2, and plots with an area of 15 m^2 (experimental units).

Treatments consisted of irrigation start times (1, 15, and 30 days after treatment application (DAT)), irrigation water retained permanently until the time of crop harvest, times of penoxsulam applications (premature and late), and penoxsulam rates (0, 24, 36, 48, and 60 g ha^{-1}).

The reagent cultivar was Qualimax 1, where it was shown with populations of 150 kg ha^{-1} of seed, which led to the establishment of a population of approximately 400 plants·m^{-2} in rows spaced 0.17 m. The choice of cultivar was held to be the most widely grown in the region of conducting the experiment.

For the spraying of herbicides was used a CO_2 pressurized backpack sprayer with bar containing four flat fan nozzles 110.02 working pressure of 20 lb in^{-2} and spray volume of 150 L ha^{-1}. At the time of first application (early), rice plants were in the 2–4 leaf stage, the plants of *Echinochloa* sp. (barnyardgrass) with 1–3 leaves. Already, for the second application (late), rice was meeting with 4 leaves and 1 tiller, plants of *Echinochloa* sp. with 4 leaves and 2 tillers. The weed population was 524 plants·m^{-2} of *Echinochloa* sp.

The data control was analyzed for homoscedasticity, transformed by arcsine $\sqrt{(x + 0,5/100)}$, and subsequently subjected to analysis of variance ($P \leq 0,05$). A comparison of means for the factors time of onset of irrigation and application time penoxsulam was made by Tukey's test ($P \leq 0,05$). The dose effects were analyzed by regression analysis using nonlinear (exponential equations) ($P \leq 0,05$ or $P \leq 0,10$).

3. Results and Discussion

The control of *Echinochloa* sp. there was interaction of the factors studied (Table 1, Figures 1 and 2). The delayed start of irrigation (15 and 30 DAT) for the two lower doses of herbicide, in general, for all evaluation periods reduced the efficiency of control *Echinochloa* sp. (Table 1).

In the evaluation performed at 10 DAT, it was noted in general that herbicide application development of late season weed control decreased levels of *Echinochloa* sp., regardless of timing of irrigation and dose used (Table 1). In other periods

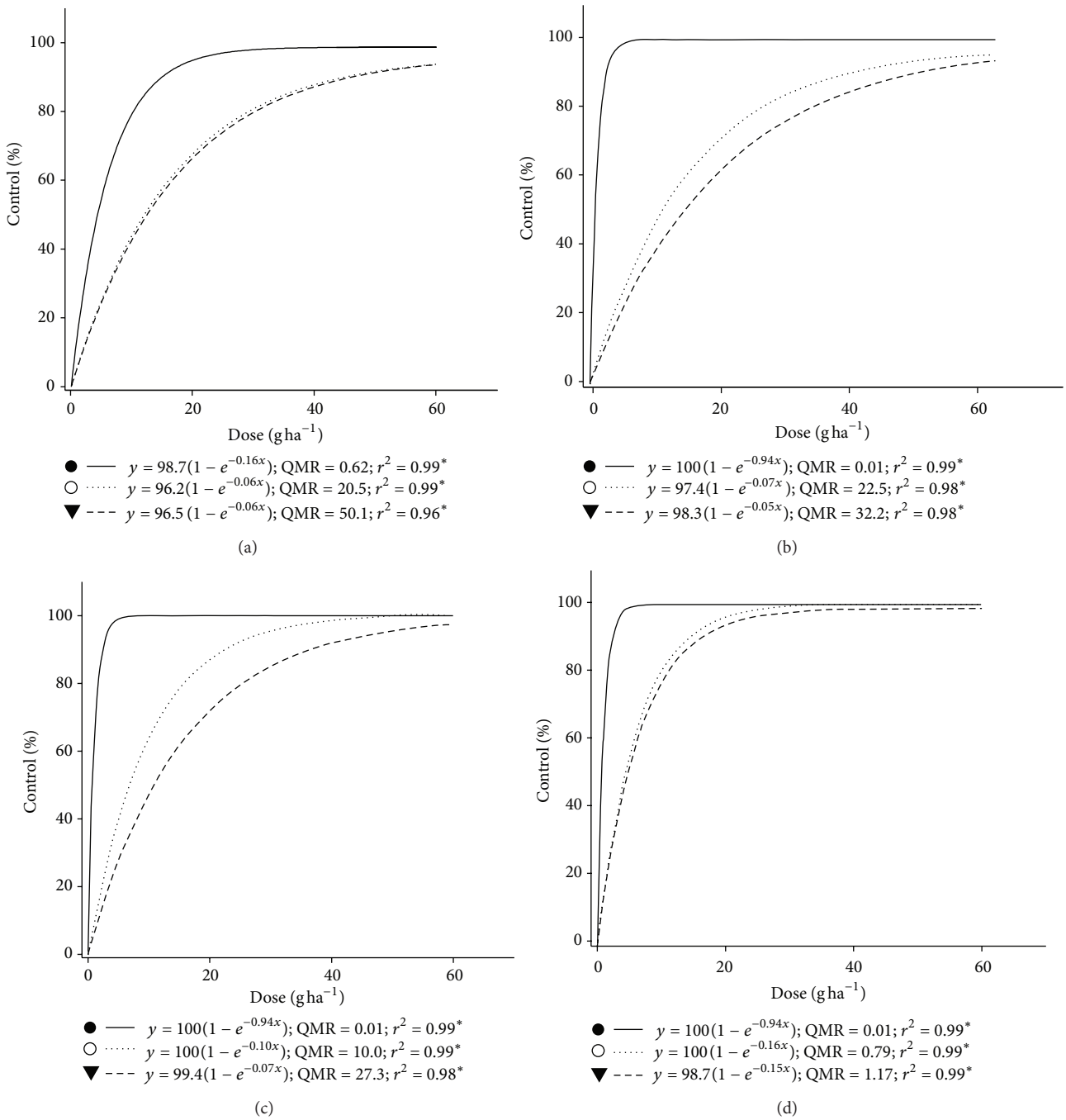

Figure 1: Control of *Echinochloa* sp. in irrigated rice, evaluated at 10 DAT (a), 20 DAT (b), 30 DAT (c), and 81 DAT (d), depending on the starting times of irrigation (• 1 DAT, O 15 DAT, and ▼ 30 DAT), penoxsulam rates, and time of application early, Rio Grande, RS (r^2: coefficient of determination; QMR: mean square; * significant, a $P \leq 0,05$).

of evaluation, in general, there was not difference between early and late herbicide application, for all doses tested. This could be because the plants of *Echinochloa* sp. at the time of application were in advanced stages of development compared to herbicide application when at an early stage of development.

The effect of dose penoxsulam, due to the factors time of flooding and application in control of *Echinochloa* sp., showed good fit of the data to the model, with r^2 of 0.88 and generally low values of QMR data demonstrating the adequacy of the model (Figures 1 and 2).

The anticipation of the onset of flooding, especially in smaller doses of the herbicide reduced the dose penoxsulam needed to obtain effective control of *Echinochloa* sp., regardless of the time of application and evaluation, as shown by the lower value of the parameter exponential model

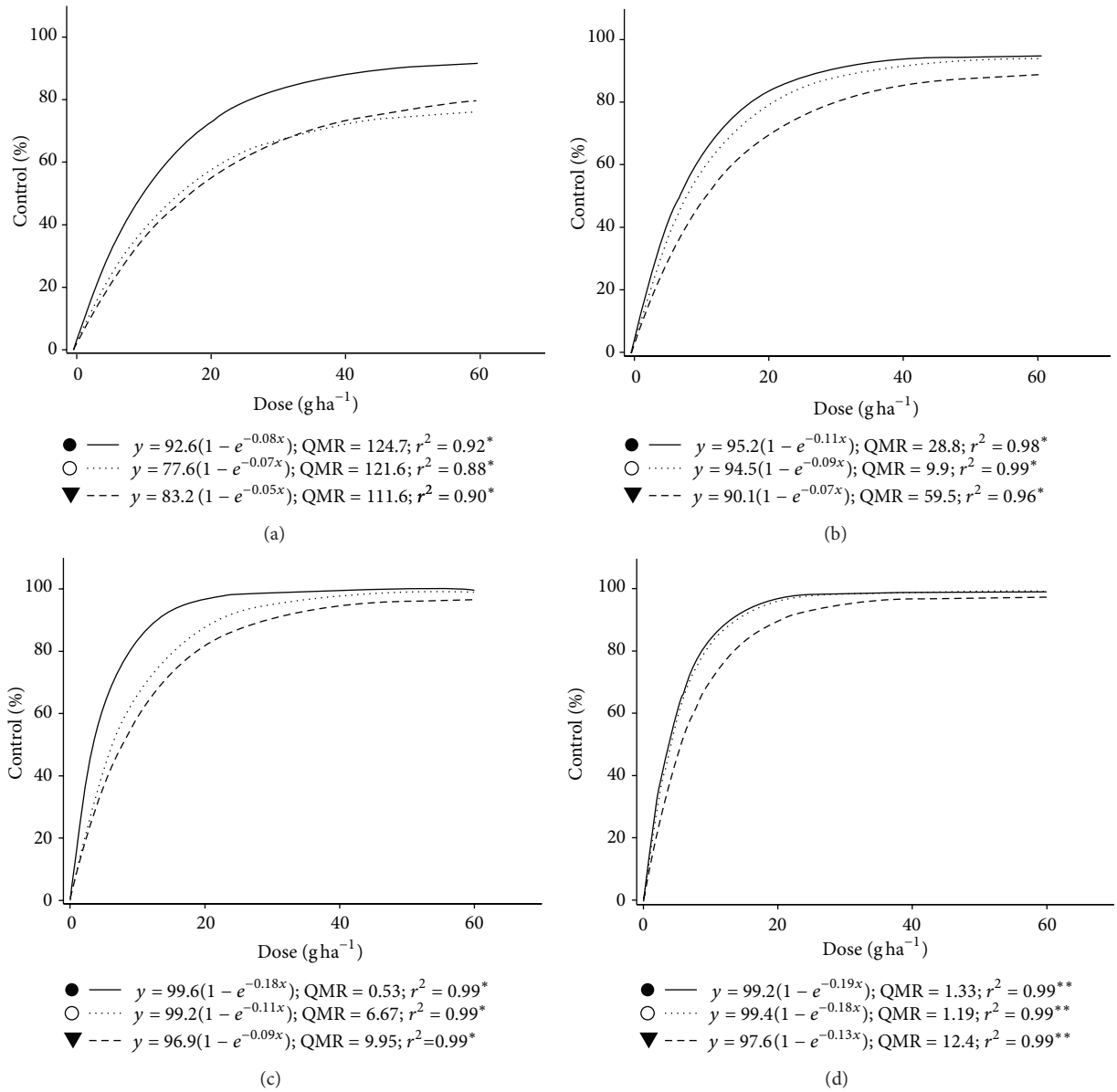

Figure 2: Control of *Echinochloa* sp. in irrigated rice, evaluated at 10 DAT (a), 20 DAT (b), 30 DAT (c), and 65 DAT (d), depending on the starting times of irrigation (• 1 DAT, O 15 DAT, and ▼ 30 DAT), penoxsulam rates, and time of application late, Rio Grande, RS (r^2: coefficient of determination; QMR: meansquare; *significant, a $P \leq 0,05$).

(Figures 1 and 2). The comparison between irrigation times based on the values of the exponential model showed that the anticipation of irrigation to 1 DAT, associated with early application, the average of four evaluation, reduced by 7,5 and 9,4 times the value found in the parameter when compared to early irrigation at 15 and 30 DAT, respectively. Performing the same comparison for the late application, it was found that the values were of 1,1 and 1,6 times lower for the early irrigation at 15 and 30 DAT.

In studies with penoxsulam, Pinto et al. [12] observed that at lower doses of herbicide control the best results were seen with the entry of water beforehand, whereas at higher doses the water inlet later allowed for better control results. This could be indicative of the residual effect of the product, which is partially offset from the time of entry of the water due to higher leaching or percolation [15].

According to Pinto et al. [12], it is possible to use lower doses of penoxsulam associated with the water inlet advance (21 DAE) to obtain similar levels of control at higher doses or delay the entry of water into the cultivation and use higher doses of herbicide [12]. Thus, Concenço et al. [17] reported efficient control barnyardgrass with the herbicides clomazone, penoxsulam and when the procedure from the beginning of the irrigation occurred at 19 and 24 DAE in different doses tested.

Settling greater than or equal to 90% as efficient control pattern [6] showed that the last two doses equal or greater than 24 g ha^{-1} showed penoxsulam control of *Echinochloa* sp., when irrigation began in the period up to 15 DAT. These results may be due to the high efficiency control *Echinochloa* sp. by penoxsulam.

The weed control in early development stage comprises the use of lower doses and early applications of herbicide, without changing the control efficiency, since then it immediately start irrigation to prevent reinfestation [6, 8].

When testing low doses of penoxsulam mixed with clomazone, Concenço et al. [16] found an earlier irrigation efficient control of *Echinochloa* sp. independent of the dose used. Results similar to the present experiment were observed by Bradley and Kendig [18]. Evaluating the effects of periods of flooding in controlling *Echinochloa* sp., Pinto et al. [19] reported that the delayed onset of irrigation in 10 days after the application of penoxsulam reduced by 26% weed control.

The delayed onset of flooding significantly affects grain yield of rice, regardless of dose and application timing penoxsulam, anticipating the start of flooding increases the efficiency of penoxsulam for control of barnyardgrass, and the delay in the entry of water is partially offset by the her-bicide [12].

Whereas the anticipation of irrigation in rice cultivation aids in weed management and serves as a preventive method preventing the emergence of new streams of plants [20], preventing reinfestation in flooded areas, the association of water management with herbicides that have residual power can increase the efficiency of control or allow dose reduction of herbicide. The beneficial effect of water depth on weed control stands out in terms of land cover, eliminating the oxygen available to the roots of the weeds [16, 17].

The anticipation of the start of irrigation to 1, 10, or 20 days after herbicide treatment increased the grain yield of rice in competition with *Echinochloa* sp. [2, 3]. In a study evaluating the effects of periods of flooding and dose penoxsulam, it was found that the delay of 10 days from the beginning of irrigation after application of this herbicide reduced on average 41% grain yield of rice [19].

Inferring the influence of the management for weed control, Pinto et al. [12] reported that the application of herbicide to retard the entrance of water, or 30 days after emergence (DAE) results in low productivity, and this fact is probably due to reinfestation of the crop due to the lack of additional effect of water on herbicide action and also the lowest residual effect due to the low dose used. This author also points out that regardless of dose or time of herbicide application, with water inlet on the farm at 21 DAE, there is an increase on average of 57% in grain yield of rice compared to 30 DAE.

4. Conclusions

The penoxsulam herbicide revealed that combined with irrigation beginning 15 days after herbicide application provided efficient control of barnyardgrass.

Conflict of Interests

The authors declare that they have no conflict of interests regarding the publication of this paper.

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