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Article

WEED PHYTOSOCIOLOGICAL SURVEY IN IRRIGATED RICE

Levantamento Fitossociológico de Plantas Daninhas na Cultura do Arroz Irrigado

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ABSTRACT - The phytosociological method helps evaluate the vegetation composition. The objective of this study was to identify and quantify the main weed species present in irrigated rice. The phytosociological survey was carried out in three mainly rice monoculture, Clearfield® technology using properties in Itaqui-RS, between 2013 and 2014. For each property and period, a ½ ha representative area was selected and 10 random samples were collected, using a quadrat square of 1 m^2. The sample colletion was conducted in two periods of time: during the irrigated rice crop initial growth and during the cereal's pre-harvesting phase. All collected plants were identified and counted, allowing for their frequency, relative frequency, density, relative density, abundance, relative abundance, relative importance index and similarity index to be calculated. Eleven weed species belonging to five families were identified. Poaceae and Cyperaceae occurred more frequently. During the initial growth of rice, the Poaceae family presented the largest index of relative importance, mainly to *Echinochloa crus-galli*, *Echinochloa colona* and *Digitaria horizontalis*. Overall, there was a reduction in plant density in the pre-harvest period. However, *Echinochloa colona* and *Oryza sativa* occurred in density levels that may interfere with the cereal yield. *Aeschynomene denticulata*, *Cyperus iria* and *Oryza sativa* are not controlled efficiently, indicating possible cases of herbicide resistance. Our conclusions emphasize the importance of correct weed species identification for the management of *Echinochloa colona* and *Cyperus ferax*. Integrated management practices are necessary for efficient weed control, avoiding productivity loss in the region's flooded rice fields.

Keywords: phytosociology, *Oryza sativa*, identification.

RESUMO - O método fitossociológico permite avaliar a composição da vegetação. Objetivou-se neste estudo identificar e quantificar as principais plantas daninhas ocorrentes na cultura do arroz irrigado. O levantamento fitossociológico foi realizado no município de Itaqui-RS, entre 2013 e 2014, em três propriedades, em que predomina a monocultura e tecnologia Clearfield®. Em cada propriedade foi selecionada uma área representativa de ½ ha, onde foram realizadas 10 amostragens aleatórias, utilizando quadrado inventário (1 m^2). A coleta ocorreu em duas épocas: durante o crescimento inicial da cultura e na pré-colheita do cereal. Após cada coleta, as plantas foram identificadas, sendo registradas a frequência, frequência relativa, densidade, densidade relativa, abundância, abundância relativa, índice de importância relativa e índice de similaridade. No total, foram identificadas 11 espécies de plantas daninhas, pertencentes a cinco famílias. As famílias Poaceae e Cyperaceae ocorreram com maior frequência. Durante o crescimento inicial do arroz, observou-se amplo índice de importância relativa da família Poaceae, principalmente para ***Echinochloa crus-galli***,

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Echinochloa colona *e* ***Digitaria horizontalis****. De modo geral, houve redução na densidade de plantas no período de pré-colheita. No entanto,* ***Echinochloa colona*** *e* ***Oryza sativa*** *ocorreram em níveis de densidade que podem interferir na produtividade do cereal.* ***Aeschynomene denticulata****,* ***Cyperus iria*** *e* ***Oryza sativa*** *não são controladas de modo eficiente, indicando possíveis casos de resistência a herbicidas. Salienta-se a importância da correta identificação das espécies para o manejo de* ***Echinochloa colona*** *e* ***Cyperus ferax****. São necessárias práticas de manejo integrado para controle eficiente das plantas daninhas, evitando perdas de produtividade em lavouras de arroz irrigado da região.*

Palavras-chave: fitossociologia, *Oryza sativa*, identificação.

INTRODUCTION

Irrigated rice growing is characterized by a high occurrence of a veriety of weed species (Sosbai, 2014). Weeds cause significant losses in rice crops, by competing for water before the flood period, for light, for mineral nutrients and through indirect actions (acting as parasites hosts), lowering both productivity and grain quality (Cobucci and Noldin, 2006). This way, they constitute the greatest biotic limiting factor to the cereal's productive potential (Agostinetto et al., 2011).

Weed interference in irrigated rice growing varies according to the weed species, the infestation intensity, the cultivar and the field handling (Panozzo et al., 2009). This way, identifying the species in an area, as well as its relative significance (frequency, density and dominance), is the first step to the adequate weed handling. Species identification and classification then allows for an informed decision on the best way to handle the weed (Oliveira and Freitas, 2008).

Correct weed identification is crucial, as each species has a different settlement potential and interference capacity among different kinds of growing practices (Cruz et al., 2009). It should also be noted that the establishment of an infesting community in a certain area varies according to each place's edaphoclimatic conditions and to the local cultivating practices. There may also occur differences among regions due to different crop implantation system.

Weed botanical identification and quantification may be achieved through the phytosociological method (Braun-Blanquet, 1979). This method may provide specific data like frequency, density and abundance, as well as the relation between each weed species and the total weed population in a given area, representing an important inference tool about the target weed flora (Erasmo et al., 2004).

The phytosociological survey is of special concern, since it will allow for decisions about which actions will be carried out in handling the weed, as well as how and when each action should be performed (Oliveira e Freitas, 2008). The Rio Grande do Sul state's Western Border is the largest irrigated rice producing region in Brazil (IRGA, 2013). Nevertheless, there are no studies on the local weed population's composition.

In this paper, we describe the phytosociological survey of weed in Rio Grande do Sul Western Border irrigated rice cultures.

MATERIAL AND METHODS

The phytosociological survey was carried out in three irrigated rice producing areas, all located in Itaqui, a city in Rio Grande do Sul Western Border, between 2013 and 2014. In this region, rice is mostly grown in soils of the classes Plinthsol, Gleysol, Chernozem and Planosol (Plintossolo, Gleissolo, Chernossolo e Planossolo, respectively, in the Brazilian Soil Classification System), making up for 76.57% of the area, occurring in a plane and lightly undulated area of restricted drainage. The most prevalent soil class is the Plinthsol Argilluvic petroplinthic euthrophic (56.78%), followed by the Gleysol Haplic Tb euthrophic typical (11,13%), the Chernozem Ebanic carbonatic vertic (7.93%) and the Planosol Haplic euthrophic arenic

(0,73%) (Bohn Gass et al., 2015). The climate is of the Cfa (Köppen) type, subtropical humid, with hot summers and without a definite dry season (Kuinchtner et al., 2001).

The studied estates are mainly dedicated to rice monoculture, using the Clearfield® production system with the Puitá INTA-CL cultivar (Sosbai, 2014). This technology uses *imidazolinone* resistant rice genotypes, aiming mainly at the handling and control of weed rice (Menezes et al., 2013). Property 1 is characterized by the growth of rice/rice and Property 2 by rice/fallow. In both cases, the Clearfield® technology has been used for the last six consecutive years, regardless the manufacturer recommendations to the contrary. In Property 3, also characterized by a rice/rice cycle, this was the first year the Clearfield® technology was used. Weed handling is achieved by the chemical method.

The phytosociological survey was conducted in two periods of time: 1) between November and December 2013, during the irrigated rice cultivation initial growth (CI) – this stage occurred up to 25 days after seeding (DAS), when the rice plants were up to the V4 stage (Counce, 2000) to a tiller, and before the chemical handling of the weed; and 2) the second collection occurred between February and March 2014, during the cereal's pre-harvesting period (PRÉ).

In properties 1 and 2, the weed gathering was conducted in November (CI) and February (PRÉ); in property 3 in December (CI) and March (PRÉ). The evaluation procedure used a quadrat square of 1 m^2, as suggested by Braun-Blanquet (1979). For each property and period, a ½ ha representative area was selected and 10 random samples were collected. After the sample gathering, the weeds found in each are were cut close to the ground, pressed between paper sheets and sent to the laboratory, where they were botanically identified into family, gender and species, by an expert and through the use of specialized literature (Lorenzi, 2014).

Besides the botanical identification, the following parameters were calculated, following Mueller-Dombois e Ellemberg (1974): frequency (F), relative frequency (Fr), density (D), relative density (Dr), abundance (A), relative abundance (Ar) and the relative importance index (Ir).

$$F = \frac{number\ of\ squares\ where\ the\ species\ was\ found}{total\ number\ of\ squares}$$

$$Fr\ (\%) = \frac{F\ x\,100}{total\ frequency\ of\ all\ species\ found}$$

$$D = \frac{number\ of\ specimens\ found\ for\ the\ species}{number\ total\ of\ squares}$$

$$Dr\ (\%) = \frac{D\ x\,100}{total\ density\ of\ all\ species\ found}$$

$$A = \frac{number\ of\ specimens\ found\ for\ the\ species}{total\ number\ of\ squares\ where\ the\ species\ was\ found}$$

$$Ar\ (\%) = \frac{A\ x\,100}{total\ abundance\ of\ all\ species\ found}$$

$$Ir\ (\%) = Fr + Dr + Ar$$

The weeds similarity index was determined between both the two different periods (CI and PRÉ) and the different properties. The index was calculated according to Sorensen (1972) proposal:

$$Similarity\ index\ (IS) = \frac{2\ x\ the\ number\ of\ species\ in\ both\ habitats}{number\ of\ species\ found\ in\ habitat\ A + number\ of\ species\ in\ habitat\ B}$$

A dissimilarity matrix by “1-IS” was generated from each similarity index. This way, it was possible to build a dendrogram by the unweighted pair-group method using arithmetic averages (UPGMA) (Sneath and Sokal, 1973).

RESULTS AND DISCUSSION

The phytosociological survey identified eleven (11) distinct weed species from five botanical families (Table 1) infesting the irrigated rice cultures in Itaqui, Rio Grande do Sul Western Border. The Poaceae was the most representative weed family found in the phytosociological survey, with six (6) species, followed by the Cyperaceae (2), the Alimastaceae (1), the Fabaceae (1) and the Malvaceae (1). With the sole exception of the *Sida rhombifolia* (Malvaceae), all species found are typical of and/or adapted to humid environments (Lorenzi, 2014).

In property 1, five weed species, grouped in four families, were identified during the initial growth (CI): Poaceae, Fabaceae, Cyperaceae and Alismataceae, with 117, 16, 10 and 2 specimens, respectively. The species with the largest relative importance index was the *Echinochloa crus-galli* (Table 2). In the pre-harvesting period, six weed species from three families were identified: Poaceae, Cyperaceae and Fabaceae, with 51, 6 and 5 specimens, respectively. The species with the largest relative importance index were the *Oryza sativa* and the *Echinochloa colona* (Table 3).

In property 2, eight weed species, grouped in four families, were identified during CI: Poaceae, Malvaceae, Cyperaceae and Fabaceae, with 361, 41, 10 and 3 specimens, respectively. The species *Digitaria horizontalis* had the largest relative importance index, followed by the *Echinochloa colona* (Table 2). In the pre-harvesting period, six weed species from the families Poaceae and Cyperaceae were identified, with 22 and 9 specimens, respectively. The species *Oryza sativa* and *Cyperus iria* obtained the largest relative importance index (Table 3).

In property 3, four weed species, grouped in two families, were identified during CI: Poaceae and Malvaceae, with 243 and 3 specimens, respectively. The *Digitaria horizontalis* had the largest relative importance index, followed by the *Echinochloa colona* (Table 2). In the pre-harvesting period, four weed species from the families Poaceae and Malvaceae were identified, with 22 and 6 specimens, respectively. The species *Digitaria horizontalis* had the largest relative importance index (Table 3).

A high relative importance index was found for the Poaceae family, specially for *Echinochloa crus-galli*, *Echinochloa colona* and *Digitaria horizontalis*, in all three observed areas, during the

Table 1 - List of weed found in the irrigated rice tillages in the city of Itaqui, Rio Grande do Sul Western Border, in properties 1, 2 and 3, distributed by family and species – 2013/2014

Family	Property	Scientific name	Brazilian common name
Alismataceae	1	*Sagittaria montevidensis* Cham. & Schltdl.	Aguapé-de-flecha
Cyperaceae	2	*Cyperus ferax* Rich.	Junquinho
	1 and 2	*Cyperus iria* L.	Junquinho
Fabaceae	1 and 2	*Aeschynomene denticulata* Rudd.	Angiquinho
Malvaceae	2 and 3	*Sida rhombifolia* L.	Guanxuma
Poaceae	2 and 3	*Digitaria horizontalis* Willd.	Capim-milhã
	1, 2 and 3	*Echinochloa colona* (L.) Link.	Capim-arroz
	1 and 2	*Echinochloa crus-galli* (L.) P. Beauv.	Capim-arroz
	2	*Leersia hexandra* Sw.	Grama-boiadeira
	1, 2 and 3	*Oryza sativa* L.	Arroz-daninho

Table 2 - First survey – Weed species found during the irrigated rice initial growth phase in properties 1, 2 and 3. Itaqui-RS, 2013

Species	NQ	NI	F	FR (%)	D (pl m^{-2})	Dr (%)	A	Ar (%)	Ir (%)
	Property 1								
A. denticulata Rudd.	09	16	0.9	28.1	1.6	11.0	1.7	9.5	48.6
C. iria L.	05	10	0.5	15.6	1.0	6.9	2.0	11.2	33.7
E. crus-galli (L.) P. Beauv.	09	107	0.9	28.1	10.7	73.8	11.8	65.9	167.8
O. sativa L.	07	10	0.7	21.9	1.0	6.9	1.4	7.8	36.6
S. montevidensis Cham. & Schltdl.	02	02	0.2	6.3	0.2	1.4	1.0	5.6	13.2
Total			3.2		14.5		17.9		
	Property 2								
A. denticulata Rudd.	03	03	0.3	6.4	0.3	0.7	1.0	1.62	8.70
C. iria L.	06	10	0.6	12.7	1.0	2.4	1.6	2.6	17.7
D. horizontalis Willd.	10	200	1	21.3	20.0	47.3	20.0	32.4	101.0
E. colona (L.) Link.	07	105	0.7	14.9	10.5	24.8	15.0	24.3	64.1
E. crus-galli (L.) P. Beauv.	03	46	0.3	6.2	4.6	10.8	15.3	24.8	41.8
S. montevidensis Cham. & Schltdl.	03	08	0.3	6.16	0.8	1.9	2.6	4.2	12.3
O. sativa L.	05	10	0.5	10.6	1.0	2.3	2.0	3.2	16.2
S. rhombifolia L.	10	41	1	21.3	4.1	9.7	4.1	6.6	37.6
Total			4.7		42.3		61.6		
	Property 3								
D. horizontalis Willd.	10	183	1.0	38.5	18.3	74.4	18.3	68.3	181.1
E. colona (L.) Link.	10	53	1.0	38.5	5.3	21.5	5.3	19.8	79.8
O. sativa L.	04	07	0.4	15.4	0.7	2.8	1.7	6.3	24.6
S. rhombifolia L.	02	03	0.2	7.7	0.3	1.2	1.5	5.6	14.5
Total			2.6		24.6		26.8		

Key: number present in squares (NQ), number of specimens (NI), frequency (F), relative frequency (Fr), Density (D), relative density (Dr), abundance (A), relative abundance (Ar) and relative importance index (Ir).

Table 3 - Second survey – Weed species found during the irrigated rice pre-harvest phase in properties 1, 2 and 3. Itaqui-RS, 2014

Species	NQ	NI	F	FR (%)	D (pl m^{-2})	Dr (%)	A	Ar (%)	Ir (%)
	Property 1								
A. denticulata Rudd.	05	05	0.5	15.2	0.5	8.1	1.0	10.6	33.8
C. iria L.	05	06	0.5	15.2	0.6	9.7	1.2	12.7	37.6
E. colona (L.) Link.	10	18	1	30.3	1.8	29.0	1.8	19.1	78.5
E. crus-galli (L.) P. Beauv.	01	01	0.1	3.0	0.1	1.6	1.0	10.6	15.3
O. sativa L.	09	28	0.9	27.3	2.8	45.2	3.1	32.9	105.4
O. sativa L.	03	04	0.3	9.1	0.4	6.5	1.3	13.8	29.4
Total			3.3		6.2		9.4		
	Property 2								
C. ferax Rich.	02	02	0.2	8.3	0.2	6.5	1.0	13.5	28.3
C. iria L.	05	07	0.5	20.8	0.7	22.6	1.4	18.9	62.3
E. colona (L.) Link.	04	05	0.4	16.6	0.5	16.1	1.2	16.2	48.9
E. crus-galli (L.) P. Beauv.	04	06	0.4	16.6	0.6	19.3	1.5	20.3	56.3
L. hexandra Sw.	03	03	0.3	12.5	0.3	9.7	1.0	13.5	35.7
O. sativa L.	06	08	0.6	25	0.8	25.8	1.3	17.6	68.4
Total			2.4		3.1		7.4		
	Property 3								
D. horizontalis Willd.	07	19	0.7	53.8	1.9	67.8	2.7	40.3	162.0
E. colona (L.) Link.	02	02	0.2	15.4	0.2	7.1	1.0	14.9	37.5
O. sativa L.	01	01	0.1	7.7	0.1	3.6	1.0	14.9	26.2
S. rhombifolia L.	03	06	0.3	23.1	0.6	21.4	2.0	29.8	74.4
Total			1.3		2.8		6.7		

Key: number present in squares (NQ), number of specimens (NI), frequency (F), relative frequency (Fr), Density (D), relative density (Dr), abundance (A), relative abundance (Ar) and relative importance index. (Ir).

rice initial growth phase. The densities of 10.7, 10.5 and 18.3 plants m^{-2}, observed respectively in properties 1, 2 and 3, are at levels capable of interfering in the studied grain yield (Tabela 2). According to Vidal (2010), the critical interference prevention period for weed in irrigated rice was found to be between 10 and 40 days after the emergence. In order to avoid eventual loses, effective control measures must be taken before that period.

Altogether, the weed plants m^{-2} density was lower in all three studied properties during the pre-harvest period, when compared to the irrigated rice initial growth period. However, in property 1 the number of *Echinochloa colona* was higher during pre-harvest, and the *Oryza sativa* species also arose. Their density levels were 1.8 and 2.8 plants m^{-2}, respectively. The most economically damaging weed in the majority of the regions composing the Rio Grande do Sul irrigated rice agro-industrial sector is the weedy rice (*Oryza sativa*) (Menezes et al., 2013).

The weedy rice emergence leads to economical, social and environmental losses (Agostinetto et al., 2005); and since this weed presents morphophysiological similarities to the rice, it is had control effectively with herbicides (Sartori et al., 2014). As for the presence of *Echinochloa* spp, studies have shown that 20 plants m^{-2} can reduce rice productivity by a margin up to 80% (Vandevender et al., 1997).

The first survey was carried out before the tillage's chemical handling; in the second survey, the reduction in the populations of certain weed species was lower than expected. According to Sosbai (2014), a minimum reduction of 90% should be expected. Nevertheless, in property 1, the *Aeschynomene denticulata* was reduced by 68.7% and the *Cyperus iria* by 40,0%, while the number of specimens in the *Oryza sativa* population grew 280%. The same happened in property 2, where the *C. iria* and the *O. sativa* populations were reduced by 30% and 20%, respectively (Tables 2 and 3).

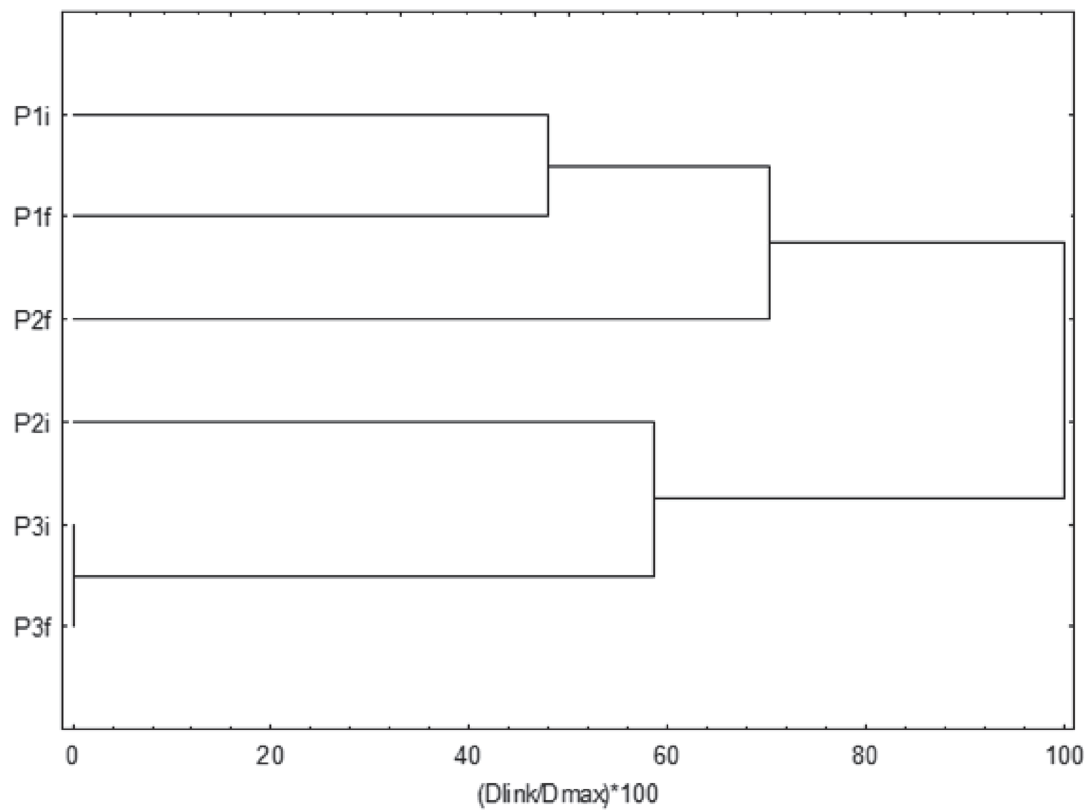
These figures may be related to some species' ability to produce two generations during the same crop, as in the case of the *Cyperus iria* (Galinato et al., 1999). However, the continuous use of the Clearfield® technology, in which the chemical handling employ herbicides with similar action mechanisms, may select for resistant weed populations. According to Lamego et al. (2009), the reiterate use of herbicides with the same action mechanisms during a long time results in the selection of resistant specimens.

Another fact corroborating the herbicide resistant flora selection hypothesis is that in property 3, where the Clearfield® technology was introduced in that same year, the same tendency was not observed. All weeds presented a satisfactory reduction, with the sole exception of the *Sida rhombifolia* (Table 3). However, as this species is more commonly found in soy cultures (Fleck et al., 2004), the correct active ingredient for its control may not have been used. So, the Clearfield® technology efficiency for weed control, when correctly used, is attested.

As for the similarity index, it allows for the evaluation of weed diversity, varying between 0 and 1. Since we used a dendrogram obtained from a dissimilarity matrix built using the grouping method (UPGMA), the lowest value indicates that all species are common in the compared areas, while the highest value indicates no common species. These informations are relevant to understand the variation of species in relation to the handling methods and practices adopted in each case (Concenço et al., 2013). So, the low and medium indexes between properties (Figure 1) show that the weed composition varied among the different studied places.

Examining the dendrogram between the two periods of time in the survey, property 3 obtained the highest similarity, with the same species being present during the irrigated rice initial growth and the pre-harvesting phases. In properties 1 and 2, a higher dissimilarity was observed between the species present in the two periods of time. This higher dissimilarity may indicate the incorrect handling of weed.

In property 1, the *Echinochloa colona* occurred only in the second evaluation. The active ingredients imazethapyr and (imazapyr + imazapic), commonly used in the Clearfield® technology for weed chemical handling, are recommended solely for the *Echinochloa crus-galli* control. The same reason would explain the appearance of *Cyperus ferax* e *Leersia hexandra*



P1i; P2i; P3i: gathering from properties 1, 2 e 3, during initial growth (CI) of the irrigated rice culture.
P1f; P2f; P3f: gathering from properties 1, 2 e 3, during pre-harvest (PRÉ) of the irrigated rice culture.

Figure 1 - Dendrogram obtained from a dissimilarity matrix built using the grouping method (UPGMA), from data gathered int the phytosociological surveys conducted in properties 1, 2 and 3, during initial growth and pre-harvest phases of the irrigated rice cultures. Itaqui-RS, 2013/2014.

during property 2 second evaluation (Tables 2 and 3). Both cases emphasize the importance of correct weed identification, as the choice of the active ingredient depends on the species present at the target place (Erasmo et al., 2004).

The present phytosociological survey results indicate that the rice monoculture, even using fallow land, associated with a rice variety with low competing capability and the inadequate use of the Clearfield® technology, does not allow for an effective weed control in the Rio Grande do Sul Western Border. An effective control requires integrated handling strategies, in order to avoid significant crop losses.

The widespread use of the Puitá INTA-CL cultivar should be reconsidered, as it presents a low competitive capability against the weed species (Rubin et al., 2014).

So, the adoption of a culture handling is indispensable, allowing for the selection of more competitive cultivars and also for culture rotation. We also underline the importance of the herbicides active ingredients rotation in the surveyed areas, since the species *Aeschynomene denticulata*, *Cyperus iria* and *Oryza sativa* are not being efficiently controlled, possibly due to the selection pressure induced by the repeated and inadequate use of the Clearfield® technology herbicides.

There is a possibility that the *Echinochloa colona* and the *Cyperus ferax* are being handled incorrectly. In order to avoid herbicide resistant weed selection under the conditions found in the studied areas, the chemical handling could be carried out with glyphosate during the pre-sowing period and with clomazone or propanil after emergence, to control the *Echinochloa colona*. For the *Cyperus ferax*, bentazone or oxyfluorfen should be used (Agrofit, 2016).

The phytosociological survey allows us to identify and to quantify the main weed species present in the region's irrigated rice tillages. It is, in this way, a fundamental tool to determine the most efficient way to handle the weed.

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