https://dx.doi.org/10.22161/ijaers.5.8.4 ISSN: 2349-6495(P) | 2456-1908(O)

Weed flora in rice areas under distinct cropping systems, herbicide and irrigation managements

Germani Concenço[1], André Andres[1], Fábio Schreiber[1], Leandro Galon[2], Mariane Camponogara Coradini[1], Caroline Hernke Thiel[1]

[1]Embrapa Temperate Agriculture, BR 392, Km 78, POBox 403, Pelotas, RS, Brazil
Email: germani.concenco@embrapa.br
[2]Department of Weed Science, Federal University of the Southern Border, Brazil
Email: galonleandro@gmail.com

***Abstract*— *We aimed to evaluate the incidence of weeds in the pre-planting of the summer crop as a function of planting system, herbicide use and irrigation management. The experiment was installed in field conditions, in RBD and 3 x 2 factorial scheme with eight replications. Treatments consisted in submitting rice to three management factors: water management – continuously flooded or intermittend irrigation (Factor A), coupled to the application (traditional control) or not (semi-ecological system) of herbicides (Factor B), and planting system – conventional soil tillage, minimum tillage and no-till systems (Factor C). One year after rice cultivation, preceding the planting of the next cropping season, phytosociological evaluations of the weed communities were carried out. We assessed the overall infestation and weed species composition, which were classified by their respective density, frequency and dominance. We also estimated the diversity coefficients of Simpson and Shannon-Weiner, and the sustainability coefficient of Shannon; treatments were also grouped by similarity in weed composition. In flood-irrigated rice, no-till provides the lowest levels of weed infestation and, together with the conventional cropping system, results in values closer to the ecological sustainability; The application of herbicides in flooded rice crops reduces weed infestation, increases diversity and equalizes the ecological sustainability, compared to areas without the application of weed management methods. However, chemical control leads to the selection of resistant or tolerant species to herbicides, such as* Polypogon *sp.; Both continuous and intermittent water management systems did not cause changes in the level of infestation, composition or diversity coefficients.*

***Keywords*— *crop management, phytosociology,* Oryza sativa.**

I. INTRODUCTION

Management systems as well as agricultural practices interfere on the agroecological dynamics of weed growth and dispersal (Salomão et al., 2012); the weed community may vary according to the cultural practices applied to the area, and their identification become indispensable to avoid crop grain yield losses by subsidizing the choice for the most adequate control method (Nordi and Landgraf, 2009).

Lack of knowledge on existing weed species in a given crop, coupled to the inadequate use of control methods, often result in the excessive use of herbicides, increasing both the environmental risk and the economical cost of the field. In this sense, the identification an quantification of these species becomes necessary to the proper selection of control methods (Silva et al., 2015).

In rice, the conventional planting system is usually adopted, but recently the minimum soil tillage in being vastly adopted; in this system, soil tillage occurs right after the harvest of the field, and a simple burndown operation is applied prior to planting, on the next cropping season. Weeds on the soil seed bank may be stimulated to germinate due to this late season soil tillage.

Irrigation management is another issue of concern for weed occurrence in rice, since the rice cropping system in Southern Brazil comprehends a definitive flooding of the area to be imposed from rice tillering start onwards. Alternative management systems aiming to save water are being tested; among them, the intermittent irrigation is gaining importance. This irrigation system comprehends alternate period of flooding and drainage of the rice fields, aiming to save water. Preliminary data show that the periods in which the field is drained, may allow the establishment of a new weed flow in the area.

The floristic survey has been shown to be tool for the recognition of infestation patterns in agricultural areas, allowing to characterize the weed community

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structure in quantitative and qualitative terms (Silva et al., 2015). For Pitelli (2000), phytosociological indexes support the analysis impacts caused by differential management systems and agricultural practices on the dynamics of weed communities in cropped fields, subsidizing the decision on the herbicides to be applied.

II. OBJECTIVE

The aim of the present study was to evaluate the incidence of weeds in the pre-planting of the summer crop as a function of the planting system, herbicide use and irrigation management.

III. MATERIAL AND METHODS

The experiment was installed in field conditions, at Embrapa Clima Temperado, Pelotas-RS, Brazil, in randomized complete blocks design, and 3 x 2 factorial scheme with plots measuring 4 m x 4 m, with eight replications. Treatments consisted in submitting rice to three management factors, as follows: water management – continuously flooded or intermittent irrigation (Factor A), coupled to the application (traditional control) or not (semi-ecological system) of herbicides (Factor B), and planting system – conventional soil tillage, minimum tillage and no-till systems (Factor C). Seeding was carried out with nine rows spaced in 0.175 m, on 09 Nov. 2016 with 100 kg ha^{-1} of the variety Guri Inta CL. The basic fertilization applied at the planting furrow consisted of 300 kg ha^{-1} of N-P-K 5-25-25.

For the planting system, in the conventional system, the area underwent plowing and disking prior to planting. In the minimum cultivation, the area underwent two light diskings, 20 days before planting rice. For no-till, the vegetation mulching was burndown 20 days prior to planting rice.

As for the chemical treatments, those without herbicide did not receive any application, not even for burndown prior to planting; the natural area mulching was only accommodated closer to soil by the planting operations. In plots where herbicides were to be applied, the area was burndown 20 days before planting, with 1440 g ha^{-1} of glyphosate. Subsequently, 73.5 g ha^{-1} of imazapyr + 24.5 g ha^{-1} of imazapic (140 $g_{c.p.}$ ha^{-1} of Kifix) + 400 g ha^{-1} de clomazone were applied right after rice planting. Thirty-five days after emergence, the application of 375 g ha^{-1} of quinclorac was necessary for control of jointvetch (*Aeschynomene* spp.).

Flood irrigation was established on 08 Dec. 2016, 20 days after crop emergence, at the beginning of tillering (~ V3), by establishing a water layer of 7 cm, which was maintained throughout the cropping cycle in treatments conttinuously flooded. In treatments with intermittent irrigation, water was replenished only when about 20% of the soil was under no water layer. After harvesting, in April 2017, ryegrass (*Lolium multiflorum*) was established as winter cover at rate of 25 kg ha^{-1} of seeds. No cuts were made to ryegrass throughout the cycle, nor any fertilizer was applied to the winter crop.

On 27 Oct. 2017, phytosociological evaluations of the weed communities present in the treatments were carried out. The sampling method adopted for surveying the weed occurrence was that of the Random Quadrats, as proposed by Barbour et al. (1998), being randomly sampled one quadrat per plot (n = 8), with 0.25 m of side. In the quadrat area, fleabane (*Conyza* spp.), fringerush (*Fimbristylis* sp.), Ryegrass (*Lolium multiflorum*) and beardgrass (*Polypogon* sp.), which predominated in the area, were quantified; the other weed species reported, were grouped as "others". Plants were cut to the soil level, packed in paper bags by species, and dried into forced air circulation oven at ± 75 ºC for three days, for later dry mass measurement. The number of plants (number m^{-2}) and its total dry mass (g m^{-2}) for each weed species (absolute infestation) were presented in histograms as a function of treatment, with the respective sampling standard errors.

The absolute infestation data set was tested for normality by the Shapiro-Wilk test, prior to estimating the density (based on number of individuals), the frequency (based on the spatial distribution of the species) and the dominance (based on capacity to accumulate mass) in relative terms, which were used to obtain the importance value for each species in each factor / treatment, according to Pandeya et al. (1968) and Barbour et al. (1998), as follows:

$$rDe = \frac{I}{RI} * 100 \quad (1)$$

$$rFr = \frac{Q}{tQ} * 100 \quad (2)$$

$$rDo = \frac{DM}{TDM} * 100 \quad (3)$$

$$IV = \frac{rDE + rFr + rDo}{3} \quad (4)$$

where *rDe* = relative density (%); *rFr* = relative frequency (%); *rDo* = relative dominance (%); *IV* = importance value (%); *I* = number of individuals of species “x” in area “r”; *TI* = total number of individuals in area “r”; *Q* = number of samples evaluated in area “r” where species “x” is present; *TQ* = total number of samples in area “r”; DM = dry mass of individuals of species “x” in area “r”; *TDM* = total dry mass of weeds in area “r”. The importance value (IV) locates each weed within the community, depending on its ability to cause damage (severity of occurrence), based on the three parameters mentioned above.

The areas were also intra analyzed by the diversity coefficients of Simpson (D) and Shannon-Weiner (H') (Barbour et al., 1998). The sustainability coefficient (SEP) was also estimated according to McManus and Pauly (1990), as follows:

$$D = 1 - \frac{\sum n_i * (n_i - 1)}{N + (N - 1)} \quad (5)$$

$$H' = \sum (p_i * \ln(p_i)) \quad (6)$$

$$SEP = \frac{Hd'}{H'} \quad (7)$$

where D = Simpson and H' = Shannon-Weiner diversity indexes (both based on density); ni = number of individuals of species "i"; N = total number of individuals in the sample; pi = proportion of individuals in the sample belonging to species "i"; SEP = Shannon-Weiner sustainability coefficient; and Hd' = Shannon-Weiner diversity index (based on dominance).

Subsequently, the areas were compared by Jaccard's binary asymmetric similarity coefficient (J). Based on the Jaccard coefficient, the similarity matrix was prepared and from it the dissimilarity matrix (1-similarity) was obtained, as follows:

$$J = \frac{c}{a + b - c} \quad (8)$$

$$Di = 1 - J \quad (9)$$

where J = Jaccard's coefficient of similarity; a = number of species in area "a"; b = number of species in area "b"; c = number of species common to areas "a" and "b"; and Di = dissimilarity.

The multivariate hierarchical clustering analysis was performed from the dissimilarity matrix by the UPGMA hierarchical clustering method (Sneath and Sokal, 1973). The critical level for group separation was based on the arithmetic mean of the similarities in the original matrix (Barbour et al., 1998), while not considering the crossing points between the same areas in the matrix (where $Di = 0$). Grouping validation was performed by the cophenetic correlation coefficient (Sokal and Rohlf, 1962), obtained by Pearson's linear correlation between the original matrix of dissimilarity and its respective cophenetic matrix. All coefficients and graphs were obtained in the statistical environment R (R Development, 2017).

All formulas and procedures, both for sampling and for describing the communities as well as species grouping, followed the recommendations by Barbour et al. (1998) for synecological analyzes.

IV. RESULTS AND DISCUSSION

Results should be concrete and meaningful for engineering scopes. You should describe limitations of your results.

4.1. Factor A – Cropping System

The absolute number of weed plants differed as function of the cropping system, being as smaller as the less intensive the soil preparation (Figure 1a), with 2108, 1963 and 1488 plants m^{-2} respectively for the conventional, minimum and no-till planting systems. The total weed dry mass, however, had opposite behavior; higher values were found in the less disturbed soils, with 223, 248 and 332 g m^{-2}, respectively for the conventional, minimum and no-till systems (Figure 1a). For the latter, even supposing the amount of weed seeds in the soil bank is high, the proportion of those able to germinate is reduced (Gomes and Christoffoleti, 2008).

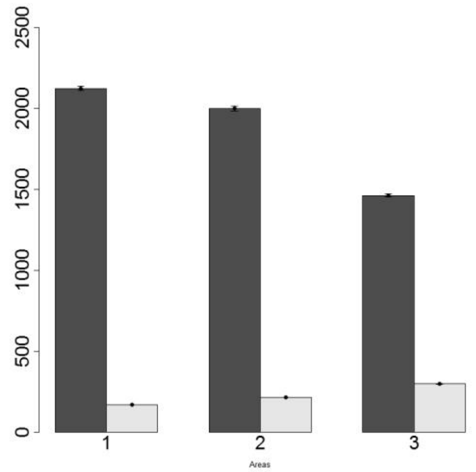

Fig.1a: Infestation and Indices of species diversity in Conventional cropping system, Minimum cropping system and No-tillage system. Density samplings (nº m^{-2}) and dry mass (g m^{-2})

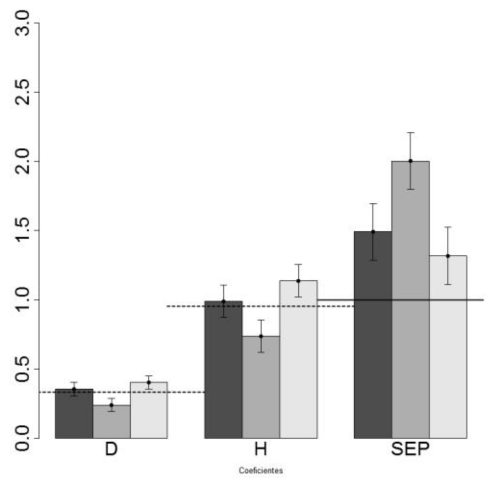

Fig.1b: Weed species diversity, D = Simpson diversity index; H' = Shannon-Weiner diversity index; SEP= Shannon-Weiner Evenness Proportion. Embrapa Clima Temperado, Pelotas-RS, 2017

https://dx.doi.org/10.22161/ijaers.5.8.4 ISSN: 2349-6495(P) | 2456-1908(O)

Analyzing the diversity indexes of Simpson (D), one may infer that the minimum cropping system, by causing only small changes in soil structure due to the slight upturning in the autumn, probably does not eliminate those weeds most adapted to the mechanical management, while at the same time it eliminates species less adapted to disturbance, resulting in lower diversity coefficient (Figure 1b). As the diversity coefficient of Shannon-Weiner was also lower in this treatment compared to the others, it is assumed that the space supposedly open in the area by the light soil tillage in autumn is not sufficient for the establishment of other alien or rare species, which would be mostly mirrored by this coefficient (Figure 1b).

According to Barbour et al. (1998), the Simpson index (D) is less sensitive to species richness, being mostly impacted by changes in occurrence of dense species. The Shannon-Weiner index, on the other side, is mostly impacted by changes in occurrence of alien or rare species (BARBOUR et al., 1998). Thus, both coefficients should be considered, since they are affected in different ways (CONCENÇO et al., 2013).

Table.1: Density, frequency, dominancy and important value of weed species in Conventional cropping system, Minimum cropping system and No-tillage system. Embrapa Clima Temperado, Pelotas-RS, 2017.

	Conventional cropping system			
Species	**de**	**fr**	**do**	**vi**
Conyza sp.	0.42	10.91	0.83	4.05
***Fimbristylis* sp.**	1.04	16.36	9.74	9.05
L. multiflorum	78.66	29.09	67.26	58.34
***Polypogon* sp.**	4.33	18.18	11.59	11.37
Others	15.54	25.45	10.57	17.19
	Minimum cropping system			
Conyza sp.	0.2	4.55	0.31	1.69
***Fimbristylis* sp.**	0.85	25	9.74	11.86
L. multiflorum	86.7	36.36	65.91	62.99
***Polypogon* sp.**	8.35	15.91	14.81	13.02
Others	3.9	18.18	9.23	10.44
	No-tillage system			
Conyza sp.	0.27	8	1.41	3.23
***Fimbristylis* sp.**	2.05	16	6.93	8.33
L. multiflorum	75.51	32	66	57.84
***Polypogon* sp.**	14.09	16	16.45	15.51
Others	8.07	28	9.21	15.09

Due to the high importance values (IV), the most favored weeds were *Fimbristylis* sp., *Lolium multiflorum* and *Polypogon* sp., with no remarkable differences between cropping systems (Table 1). *Conyza* sp. was less evident in the minimum tillage compared to the other systems, due to inherent characteristics of the species, as pointed ou by Concenço & Concenco (2016); on the one hand, this species is relatively sensitive to soil disturbance, which supports its greater occurrence in no-till. By being highly prolific, *Conyza* sp. occupies the available space, just as reported for the conventional tillage. In the minimum tillage, the small soil disturbance associated to the presence of straw cover ended up by reducing its occurrence.

In general terms, the no-till and the conventional systems were similar in terms of species diversity, while the minimum tillage differed; the latter seems to have not contributed for neither the elimination of the weeds present, nor the emergence of new weeds (Table 1). This reflected in the SEP sustainability coefficient, which was most distant from "1" (the theoretically ideal value) in this treatment, although none of the cropping systems presented adequate results (Figure 1b).

Cruz et al. (2009) reported that areas rotated with soybean, maize and irrigated rice in no-till, under central pivot irrigation, showed greater weed diversity. Thus, it can be hypothesized that crop rotation, succession and tillage system diversity contribute for adequate diversity and sustainability into a cropping system. The data corroborate with Ceolin et al. (2016), who reported that ryegrass, planted as winter cover crop in rice growing areas, was efficient in reducing weed occurrence. In flooded rice areas without crop rotation (rice / fallow) for more than five years, Erasmo et al. (2004) found higher prevalence of weeds from Poaceae and Asteraceae families. When rotated with soybeans, Cyperaceae also took importance.

The germination flow of weed seeds under no-till is mainly due to changes in soil temperature and moisture conditions, since there is no disturbance that could stimulate germination of certain species. During winter, the reduced soil temperature favors the germination of hibernal weeds, while estival species are favored during the warmer cropping season (Gomes et al., 2008).

In general terms, the cropping system does not seem to be the main factor in the definition of weeds occurring in lowland rice areas, since the importance values for the monitored species and also for the other species present in the areas were very similar between the three soil tillage systems (Table 1). This was corroborated by the similarity analysis (data not shown), which indicated J = 100% among all treatments, regarding exclusively species composition. As expected, ryegrass predominated because it was an introduced species, which

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may have contributed to the suppression of weeds and the equalization of infestation between the different systems.

Comparing crop production systems, Pacheco et al. (2016) verified that for rice preceded by soybean in the summer and *Pennisetum glaucum* in winter, the conventional system resulted in fewer weeds established in the area during rice cultivation, compared to no-till. The author attributed the fact to poor soil cover provided by *P. glaucum.* Therefore, the no-till system seems to be efficient in weed suppression only if there is efficient soil cover and adequate straw volume, which can be achieved by additional sowing of some winter cover crop such as ryegrass. This is one of the few cover / grazing species adapted to floodplain environments, achieving high yields of dry mass with small addition of nitrogen. It presents high nutrient cycling capacity, which justifies its use prior to rice cultivation, besides being suitable for both for soil cover and animal grazing (Conte, 2007; Correia et al., 2013).

4.2. Factor B – Herbicide Application

There was reduction in weed density when subjected to herbicide application, but the weed dry mass remained unchanged (Figure 2a). In absence of herbicide application, around 2420 plants m^{-2} were reported, while in plots with herbicide application, less than 1500 plants m^{-2} were observed.

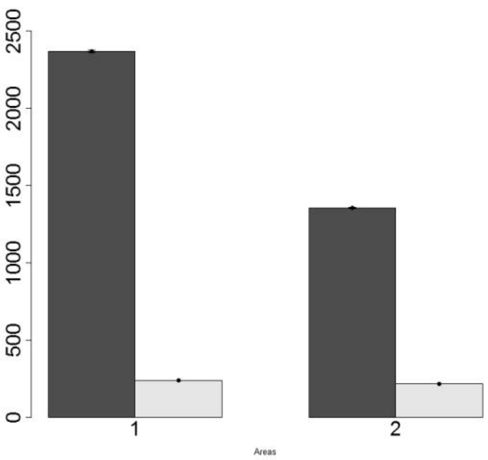

Fig. 2a: Infestation and Indices of species diversity when non-applied and applied herbicides. Density samplings (n^o m^{-2}) and dry mass (g m^{-2})

Both the Simpson and Shannon-Weiner diversity indexes were higher when herbicides were applied compared to herbicide-free plots (Figure 2b). Considering that these indices take into account both the number of individuals of each species and the balance in occurrence between species, it can be inferred that in areas with no herbicide application, only certain species predominated and inhibited the others, which reduced the "D" diversity coefficient. Plants with early establishment have advantage in the use of environmental resources; they can occupy the available space faster and inhibit later-emerging weeds (Fleck et al., 2003).

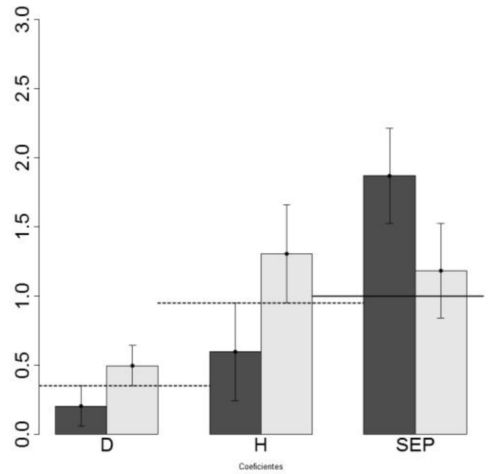

Fig.2b: Weed species diversity, D = Simpson diversity index; H' = Shannon-Weiner diversity index; SEP = Shannon-Weiner Evenness Proportion. Embrapa Clima Temperado, Pelotas-RS, 2017

The "D" index gives greater weight to the abundant species, and the data indicate that herbicide application may not have caused effective control over certain highly prolific species, increasing in this situation the abundance of these in the area. In addition, it was reported reduced emergence of rare species, which may have been eliminated due to the herbicide action spectrum, which affected the H' coefficient. From this point of view, the application of herbicides may have been positive in eliminating some plant species that could be harmful. This does not mean, however, that areas with herbicide application is always more interesting from the point of view of the productive system.

The SEP index showed that in plots without herbicides, most species invested more in dry mass accumulation (competitive strategy based on dominance) compared to the number of individuals, inferring that the environment is very likely rich in resources and able to supply the demand of the plants present. Moreover, the available space seems to be mostly occupied, since the increase in density was not the predominant competitive strategy. On the other hand, herbicide applications eventually balanced the population of the species, with equalization between density and dominance, which provided SEP ≈ 1.0 (Figure 2b).

Regarding the phytosociological characterization, ryegrass showed higher values compared to the other species, most probably because it was planted on purpose,

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for both treatments (with and without herbicide) (Table 2). *Fimbristylis* sp. and the other unidentified species, were more affected by herbicide residuals, showing reduction in all indices evaluated. However, by eliminating some species, others end up occupying the space, such as *Conyza* sp. and *Polypogon* sp., which were favored in treatments under herbicide applications. This advantage can be attributed to the fact that these species may present a certain tolerance to the herbicide, or even resistance, as in the case of *Conyza* sp. to glyphosate (Moreira et al., 2007; Lamego and Vidal, 2008; Trezzi et al., 2011).

Table.2: Density, frequency, dominancy and important value of weed species when non-applied and applied herbicides. Embrapa Clima Temperado, Pelotas-RS, 2017.

	Non-applied herbicide			
Species	**de**	**fr**	**do**	**vi**
Conyza sp.	0.17	5.56	0.25	1.99
Fimbristylis sp.	1.27	29.17	11.61	14.02
L. multiflorum	88.71	33.33	74.76	65.6
Polypogon sp.	0.28	5.56	0.49	2.11
Others	9.57	26.39	12.89	16.28
	Applied herbicide			
	de	**fr**	**do**	**vi**
Conyza sp.	0.54	10.26	1.66	4.15
Fimbristylis sp.	1.18	10.26	5.08	5.51
L. multiflorum	66.75	30.77	56.91	51.48
Polypogon sp.	22.38	26.92	30.48	26.59
Others	9.15	21.79	5.87	12.27

4.3. Factor C – Irrigation Management

Marchezan et al. (2004), evaluating the performance of rice genotypes submitted to different water management systems, verified that the continuous water layer from tillering start to harvest, when associated with adequate soil preparation, suppressed most grass weeds, mainly barnyardgrass (*Echinochloa crusgalli*).

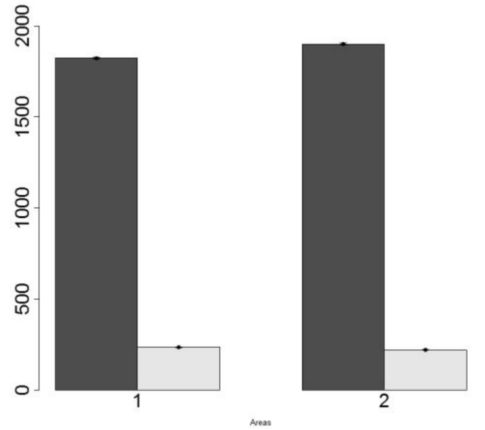

Fig.3a: Infestation and Indices of species diversity in continuous and intermittent water management. Density samplings (nº m^{-2}) and dry mass (g m^{-2})

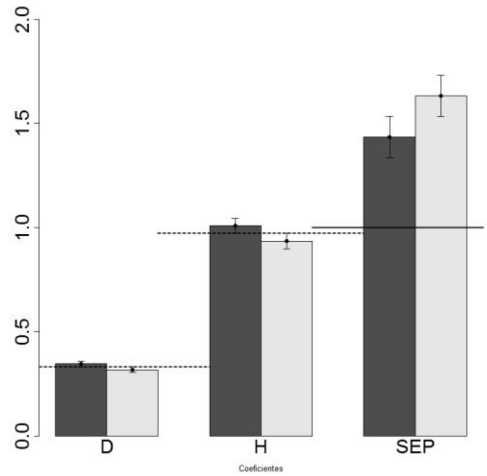

Fig.3b: Weed species diversity, D = Simpson diversity index; H' = Shannon-Weiner diversity index; SEP= Shannon-Weiner Evenness Proportion. Embrapa Clima Temperado, Pelotas-RS, 2017.

However, for the present study, when surveying the weed community after harvest in both irrigation managements, the variations were discrete for both species density and dry mass (Figure 3a). The species diversity indexes, both D and H', also suggest occurrence of the same weed species in both water management systems (Figure 3b). The SEP index indicated that the system with continuous water layer (continuously flooded) is most closer to the ecological sustainability compared to the intermittent water management (Figure 3b).

Table.3: Density, frequency, dominancy and important value of weed species in continuous and intermittent water management. Embrapa Clima Temperado, Pelotas-RS, 2017.

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Continuous Management				
	de	fr	do	vi
Conyza sp.	0.33	20	0.87	7.07
Fimbristylis sp.	1.43	20	7.95	9.79
L. multiflorum	79.7	20	67.8	55.84
Others	9.91	20	9.64	13.18
Polypogon sp.	8.6	20	13.8	14.12
Intermittent Management				
	de	fr	do	vi
Conyza sp.	0.28	20	0.97	7.08
Fimbristylis sp.	1.05	20	9.11	10.05
L. multiflorum	81.66	20	64.69	55.45
Others	8.94	20	9.47	12.8
Polypogon sp.	8.07	20	15.76	14.61

The high SEP observed for both water managements show that the greatest investment of weeds in dry mass accumulation may be due to the favorable environmental conditions to which they were submitted, and the increase in density is natively limited by the presence of the water layer. Therefore, continuous and intermittent irrigation managements were very similar in density, frequency and dominance of the evaluated species (Table 3). It is proposed that, under flood conditions, competitive strategies based on dominance tend to be preponderant for success in establishment of a certain weed species.

V. CONCLUSIONS

In flood-irrigated rice cultivation, the no-till planting system provides the lowest levels of weed infestation and, together with the conventional cropping system, results in values closer to the ecological sustainability.

The application of herbicides in flooded rice crops reduces weed infestation levels, increases diversity coefficients and equalizes the ecological sustainability, compared to areas without the application of weed management methods. However, chemical control leads to the selection of resistant or tolerant herbicide species, such as *Polypogon* sp.

Both continuous and intermittent water management systems did not cause significant changes in the level of infestation, composition or diversity coefficients in rice areas.

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