Revista Brasileira de Herbicidas, v.14, n.2, p.128-140, abr./jun. 2015 (ISSN 2236-1065)
DOI: http://dx.doi.org/10.7824/rbh.v14i2.405 www.rbherbicidas.com.br

Efficacy and phytotoxicity of herbicides applied for the handling of weeds that infest wheat[1]

Eficácia e fitotoxicidade de herbicidas aplicados para manejo de plantas daninhas infestantes do trigo

Leandro Galon[2]*; Camile Thais Castoldi[2]; César Tiago Forte[2]; Renato Kujawiski[2]; Felipe Adelio de David[2]; Gismael Francisco Perin[2]; André Luiz Radunz[2]; Luciane Renata Agazzi[2]; Joselaine Rossetti[2]; Lauri Lourenço Radunz[2]

Abstract - The objective of this paper was to identify alternatives for the chemical handling of weeds that infect wheat, as well as verifying the phytotoxicity of herbicides on the crop. The experiment was carried out in randomized blocks, organized in a factorial design of 2x 13, with four repetitions. The wheat crops were allocated to factor A (Quartzo and Pioneiro) and the herbicides to factor B (iodosulfuron – 0,100 kg ha^{-1}; imazapic + imazapyr – 0,140 kg ha^{-1}; clomazone 0,800 L ha^{-1}; imazethapyr + imazapic – 1,250 L ha^{-1}; propanil – 6,000 kg ha^{-1}; oxyfluorfen – 1,000 L ha^{-1}; penoxsulam – 0,175 L ha^{-1}; metsulfuron-methyl – 0,0033 kg ha^{-1}; 2,4-D – 1,250 L ha^{-1}; cyhalofop-p-buthyl – 1,380 L ha^{-1}; pyroxsulam – 0,400 L ha^{-1}), plus two controls, one weeded and another one infested. Iodosulfuron, propanil, oxyfluorfen, metsulfuron-methyl, 2,4-D, cyhalofop-p-buthyl, penoxsulam and pyroxsulam cause values inferior to 5.5% of phytotoxicity to wheat crops and, in general, they did not differ from the weeded and infested controls. The greatest phytotoxic effects were caused by imazethapyr + imazapic, clomazone and imazapic + imazapyr on the wheat crops. The application of iodosulfuron, imazethapyr + imazapic, imazapic + imazapyr and pyroxsulam presented elevated control percentage of ryegrass, with rates above 95.5%. Imazethapyr + imazapic, clomazone and imazapic + imazapyr presented the greatest phytotoxicity on the wheat crops. Iodosulfuron, imazethapyr + imazapic, clomazone and imazapic + imazapyr and pyroxsulam showed the best controls for ryegrass. Iodosulfuron presented lower influence on the components of wheat grains yield when compared to the other herbicides.
Keywords: chemical control; *Lolium multiflorum*; *Triticum aestivum*

Resumo - Objetivou-se com o trabalho identificar alternativas para o manejo químico de plantas daninhas infestante do trigo, bem como verificar a fitotoxicidade de herbicidas sobre a cultura. Instalou-se o experimento em blocos casualizados, arranjado em esquema fatorial 2 x 13, com quatro repetições. No fator A, alocou-se as cultivares de trigo (Quartzo e Pioneiro) e no B os herbicidas (iodosulfuron – 0,100 kg ha^{-1}; imazapic + imazapyr – 0,140 kg ha^{-1}; clomazone 0,800 L ha^{-1}; imazethapyr + imazapic – 1,250 L ha^{-1}; propanil – 6,000 kg ha^{-1}; oxyfluorfen – 1,000 L ha^{-1}; penoxsulam – 0,175 L ha^{-1}; metsulfuron-methyl – 0,0033 kg ha^{-1}; 2,4-D – 1,250 L ha^{-1}; cyhalofop-p-buthyl – 1,380 L ha^{-1}; pyroxsulam – 0,400 L ha^{-1}), mais duas testemunhas uma capinada e outra infestada. O iodosulfuron, propanil, oxyfluorfen, metsulfuron-methyl, 2,4-D, cyhalofop-p-buthyl,

[1] Received for publication on 08/21/2015 and approved on 09/22/2015.
[2] Universidade Federal da Fronteira Sul (UFFS), Câmpus Erechim. Erechim, RS, BR. Email: leandro.galon@uffs.edu.br. (*autor para correspondência).

penoxsulam e pyroxsulam ocasionaram valores inferiores a 5,5% de fitotoxicidade às cultivares de trigo e de modo geral não diferiram das testemunhas capinada e infestada. Os maiores efeitos fitotóxicos foram ocasionados pelo imazethapyr + imazapic, clomazone e imazapic + imazapyr sobre as cultivares de trigo. A aplicação de iodosulfuron, imazethapyr + imazapic, imazapic + imazapyr e o pyroxsulam apresentaram elevados percentuais de controle do azevém, com índices superiores a 95,5%. O imazethapyr + imazapic, clomazone e imazapic + imazapyr apresentaram as maiores fitotoxicidades sobre as cultivares de trigo. O iodosulfuron, imazethapyr + imazapic, clomazone e imazapic + imazapyr e o pyroxsulam demonstraram os melhores controles do azevém. O iodosulfuron apresentou a menor influência sobre os componentes do rendimento de grãos do trigo ao se comparar com os demais herbicidas.
Palavras-chaves: controle químico; *Lolium multiflorum*; *Triticum aestivum*

Introduction

Wheat (*Triticum aestivum* L.) is the second most produced cereal in the world, and it is mainly destined for human and animal feeding (ABITrigo, 2012). In the Brazilian scenario, the south region represents more than 92% of the production, and Rio Grande do Sul (RS) is responsible for producing approximately 25% of the national volume of wheat grains in the crops of 2014/15 (Conab, 2015).

The agronomic performance of wheat crops, as well as the productivity and the quality of grains, can be compromised by several factors, among them the competition against the weeds. The weeds compete with the crops for the resources available in the environment, release allelopathic substances and can host pests and diseases, causing productivity losses and influencing the quality of grains (Galon et al., 2010; Paula et al., 2011; Lamego et al., 2013).

Among the species of weeds that infest the wheat crops and strongly harm the productivity and the quality of harvested grains, we can highlight the Ryegrass (*Lolium multiflorum* Lam.). Ryegrass has characteristics that provide a high competitive ability regarding the wheat crops, and it can emphasize the natural reseeding and the great capacity of tillering (Kissmann e Groth, 1997; Rigoli et al., 2009), a fact that in association with morphological and physiological similarities and the wheat crop, makes it difficult to perform a chemical control (Galon et al., 2010). Along with these characteristics, some aggravating factors for the handling of ryegrass are the elevated seed bank in the soil, resulting from the use of a species in the pastures of animals and/or dead coverage, and the occurrence of resistance to herbicides inhibitors of EPSPs, ACCase and ALS, the most used ones currently for the desiccation or control of this weed in the crops of wheat in post-emergency.

It is worth highlighting the increase in cases of weeds resistance, especially due to the pressure of the selection that results from the constant and abusive application of herbicides with the same action mechanism (Costa and Rizzardi, 2014). It is, in general, a consequence of the existence of few alternatives of chemical molecules recommended for the control of infecting weeds in a certain crop, such as in the case of wheat.

As a control method, the weeds that infest the wheat crop, especially the ryegrass, is done with herbicides (Vargas and Roman, 2005; Galon et al., 2010), mainly due to the practicality, efficiency and lower cost when compared to other control methods (Christoffoleti et al., 2006). However, the herbicides can have direct and indirect effects in the growth and development of plants (Das et al., 2003; Rizzardi et al., 2003), provoke alterations in the physiological and metabolic processes of the plants (Rizzardi et al., 2003), besides causing an impact to the agroecosystems when used incorrectly (Scremin et al., 2010).

The same way, the cultivars may present different responses in face of the application of herbicides for the control of weeds due to their different genetic characteristics such as size, leaf interception, root volume, leaf area, tillering capacity, competitive ability, and others. That fact was already described in other studies involving sugar cane (Ferreira et al., 2005; Galon et al., 2009), the wheat (Paula et al., 2011), the rice (Pinto et al., 2008) and the soy (Agostinetto et al., 2009).

Thus, it becomes important to test new alternatives of herbicides, even if they are not registered for the crop, to evaluate the efficacy of weeds control, the phytotoxicity to wheat and the possibility of handling weeds that are resistant to the current molecules used for this end.

Therefore, the objective of this paper was to identify possible alternatives for the chemical handling of weeds that infest wheat, as well as verifying the phytotoxicity of herbicides on the crop.

Material and Methods

The experiment was carried out in the field of an experimental area of Colégio Agrícola Estadual Ângelo Emílio Grando, in the city of Erechim/RS, in the agricultural year 2012/13. The soil of the experimental area is classified as alumino Oxisol, mapping unit of Erechim (Embrapa, 2013). The sowing of wheat was done in a tillage system on straw and, 15 days before this operation, the vegetation was desiccated with the glyphosate herbicide in the dose of 1.080 g ha^{-1} of acid equivalent.

The pH and the soil fertility correction was carried out according to the soil analysis, following the technical recommendations of fertilization for the barley crop (ROLAS, 2004). Each experimental unit was composed of an area of 11.05 m^2 (5 x 2.21 m), where they were sowed individually on 06/27/2012, the Quartzo and Pioneiro cultivars in the spacing between rows of 0.17 m, with density of 140 and 160 kg ha^{-1} of seeds, obtaining 70 and 90 plants per meter of row, respectively, for both cultivars. As a nitrogen topdressing, urea was applied in two moments, the first one in the beginning of the tillering stage and the second in the stage of elongation of stems, in the doses of 150 kg ha^{-1} urea, in each period.

The experiment was carried out in a randomized blocks design, organized in a factorial design of 2 x 13, with four repetitions. The wheat crops were allocated to factor A (Quartzo and Pioneiro) and the herbicides to factor B (iodosulfuron – 0,100 kg ha^{-1}; imazapic + imazapyr – 0,140 kg ha^{-1}; clomazone 0,800 L ha^{-1}; imazethapyr + imazapic – 1,250 L ha^{-1}; propanil – 6,000 kg ha^{-1}; oxyfluorfen – 1,000 L ha^{-1}; penoxsulam – 0,175 L ha^{-1}; metsulfuron-methyl – 0,0033 kg ha^{-1}; 2,4-D – 1,250 L ha^{-1}; cyhalofop-p-buthyl – 1,380 L ha^{-1}; pyroxsulam – 0,400 L ha^{-1}), plus two controls, one weeded and another one infested. Imazapic + imazapyr and imazethapyr + imazapic are commercial mixtures formulated by the company that owns the molecules. Every herbicide received the adjuvant recommended by their respective manufacturer. Clomazone and oxyfluorfen were applied in pre-emergency and, all the others, during the crop post-emergency, when the Quartzo and Pioneiro cultivars were with four leaves to two tillers and the ryegrass was in the stage of two leaves to one tiller. The average density of ryegrass in the experimental area was 86 plants m^{-2}.

The application of the herbicides was done with a precision backpack sprayer, pressurized by CO_2, equipped with four spray nozzles in the form of a fan DG 110.02, under constant pressure of 196,1 kPa and travel speed of 3.6 km h^{-1}, which provided an output of 150 L ha^{-1} from each herbicide spray. The environmental conditions at the moment of the application herbicides in pre and post emergency are described on Table 1.

Table 1. Environmental conditions at the time of application of treatments in pre and post-emergence of the wheat crop and weed. UFFS, Erechim, 2012/13.

Application time	Luminosity (%)	Temperature (ºC)	Relative Moisture (%)	Soil conditions	Wind speed (km h^{-1})
Pre-emergence	100	18	77%	Moist	04
Post-emergence	100	19	70%	Moist	03

The variables evaluated were phytotoxicity to the wheat plants and the control of ryegrass at 07, 14, 21, 28, 35 and 42 days after the application of treatments (DAT), besides the control of ryegrass during blossoming and wheat pre-harvest. To evaluate the phytotoxicity and the control of herbicides were given percentage scores, with zero (0%) being given to treatments with the absence of ryegrass or phytotoxicity control and one hundred (100%) to the total control of the weed or complete death of wheat plants, according to the methodology proposed by SBCPD (1995).

Also, in the pre-harvest of wheat, it was determined: the number of cobs in an area of 0.25 m^2 (0.5 x 0.5 m) in the center of each experimental unit; and the amount of sterile and full grains per cob. At the wheat harvest, the grains productivity (kg ha^{-1}) and the mass of 1,000 grains (g) were determined. To determine the number of full grains and the number of sterile grains per cob, 10 cobs were harvested randomly from each experimental unit from the two wheat cultivars, conditioning them in paper bags and performing the determinations in the Seeds Laboratory at UFFS, Erechim Campus.

The harvest of the wheat cultivars was carried out when the grains reached 15% humidity in a useful area of 4.5 m^2 per experimental unit, performing the trail later on. Finally, the mass of one thousand grains (g) was also determined, containing 8 samples of 100 grains each, and weighting them in an analytical scale. For the analyses, the humidity of the grains was adjusted for 13% and the production data were extrapolated to kg ha^{-1}.

The data was submitted to the variance analysis by the F test and, when significant, the averages of the treatments were compared by the Tukey test ($P<0.05$).

Results and Discussion

The results show an interaction among the factors tested (cultivars of wheat *versus* herbicides), for all the evaluated variables. The phytotoxicity of the crop presented a different response regarding the treatments applied. Herbicides iodosulfuron, propanil, oxyfluorfen, metsulfuron-methyl, 2,4-D, cyhalofop-p-buthyl, penoxsulam and pyroxsulam presented values below 5.5% for Quartzo and Pioneiro cultivars in all times of evaluation (from day 07 to day 42 after the application of treatment - DAT) and, in general, did not differ from the controls, which did not receive any application (Table 2). It is important to highlight that these herbicides presented low indexes of phytotoxicity on wheat plants, disappearing and the injury symptoms disappeared completely after 42 DAT. Vargas and Roman (2005), when evaluating the effect of herbicides in winter crops, saw a selectivity of metsulfuron-methyl, 2,4-D and iodosulfuron for wheat, triticale and rye crops, which corroborates what was observed in this study. Galon et al. (2014a), when evaluating the phytotoxicity of the same herbicides applied on different genotypes of barley, observed similar results to the ones found in this paper.

According to the results of Table 2, herbicides imazethapyr + imazapic, clomazone and imazapic + imazapyr caused the greatest phytotoxic effects for the wheat plants in the evaluations performed at 07, 14, 21, 28, 35 and 42 DAT. However, it can be seen that the cultivars responded differently to the application of treatments, and clomazone provoked the greatest phytotoxicity on Quartzo cultivar compared to Pioneiro, in all evaluated species (Table 2). The commercially formulated mixtures, on the other hand, composed by imazapic + imazapyr, at 14 and 21 DAT, and imazethapyr + imazapic, at 28, 35 and 42 DAT, caused higher phytotoxicity on Pioneiro cultivar when comparing to Quartzo (Table 2).

Table 2. Phytotoxicity (%) of wheat crop by applying herbicides on wheat cultivars. UFFS/Erechim/RS, 2012/13.

Treatments	Phytotoxicity (%)					
	07 DAT[1]		14 DAT		21 DAT	
	Quartzo	Pioneiro	Quartzo	Pioneiro	Quartzo	Pioneiro
Iodosulfuron	3.0 Ca[2]	3.5 Ca	3.8 CDa	3.3 CDa	2.0 Ca	2.0 DEa
Imazethapyr + imazapic	28.0 Ba	26.8 Ba	81.8 Ba	81.8 Ba	88.5 Ba	88.8 Ba
Clomazone	88.8 Aa	85.3 Ab	87.0 Aa	80.3 Bb	85.8 Ba	71.8 Cb
Imazapic + imazapyr	27.0 Ba	28.5 Ba	82.0 Bb	90.0 Aa	94.0 Ab	96.5 Aa
Propanil	2.3 CDa	3.3 Ca	2.3 CDa	2.5 CDa	1.8 Ca	0.0 Ea
Oxyfluorfen	2.3 CDa	2.8 CDa	1.8 CDa	2.8 CDa	0.0 Ca	0.0 Ea
Metsulfuron-methyl	2.3 CDa	2.5 CDa	1.8 CDa	2.5 CDa	0.0 Ca	0.0 Ea
2.4-D	4.5 Ca	3.0 Ca	2.5 CDa	2.5 CDa	0.0 Ca	0.0 Ea
Cyhalofop-p-buthyl	2.8 CDa	2.5 CDa	4.5 Ca	5.3 Ca	2.8 Ca	3.3 DEa
Penoxsulam	2.8 CDa	3.0 Ca	2.8 CDa	3.8 CDa	2.8 Ca	2.5 Da
Pyroxsulam	4.3 Ca	4.3 Ca	4.3 Cda	3.3 CDa	3.0 Ca	4.3 Da
Control weeded	0.0 Da	0.0 Da	0.0 Da	0.0 Da	0.0 Ca	0.0 Ea
Control infested	0.0 Da	0.0 Da	0.0 Da	0.0 Da	0.0 Ca	0.0 Ea
CV (%)	9.06		8.52		6.50	

Treatments	Phytotoxicity (%)					
	28 DAT		35 DAT		42 DAT	
	Quartzo	Pioneiro	Quartzo	Pioneiro	Quartzo	Pioneiro
Iodosulfuron	1.0 Da	1.0 Da	0.5 Ca	0.0 Da	0.0 Ca	0.0 Da
Imazethapyr + imazapic	66.3 Cb	81.8 Ba	68.8 Bb	76.8 Ba	73.3 Bb	79.0 Ba
Clomazone	75.5 Ba	55.5 Cb	78.8 Ba	60.0 Cb	77.8 Ba	61.3 Cb
Imazapic + imazapyr	100.0 Aa	100.0 Aa	100.0 Aa	100.0 Aa	100.0 Aa	100.0 Aa
Propanil	0.0 Da	0.0 Da	0.0 Ca	0.0 Da	0.0 Ca	0.0 Da
Oxyfluorfen	0.5 Da	0.0 Da	0.0 Ca	0.0 Da	0.0 Ca	0.0 Da
Metsulfuron-methyl	0.0 Da	0.0 Da	0.0 Ca	0.0 Da	0.0 Ca	0.0 Da
2.4-D	0.0 Da	0.0 Da	0.0 Ca	0.0 Da	0.0 Ca	0.0 Da
Cyhalofop-p-buthyl	2.0 Da	0.5 Da	0.5 Ca	0.0 Da	0.0 Ca	0.0 Da
Penoxsulam	1.3 Da	1.5 Da	0.0 Ca	0.0 Da	0.0 Ca	0.0 Da
Pyroxsulam	0.5 Da	0.0 Da	0.5 Ca	0.0 Da	0.0 Ca	0.0 Da
Control weeded	0.0 Da	0.0 Da	0.0 Ca	0.0 Da	0.0 Ca	0.0 Da
Control infested	0.0 Da	0.0 Da	0.0 Ca	0.0 Da	0.0 Ca	0.0 Da
CV (%)	13.7		24.34		19.05	

[1]DAT: days after treatment. [2] Averages followed by the same uppercase on column and lowercase on line at each time of evaluation, do not differ by Tukey test at 5% of probability.

It is possible highlight also that, when comparing the two mixtures, it was observed a higher effect of imazapic + imazapyr compared to imazethapyr + imazapic on the wheat cultivars, where the first caused full death of wheat plants after 28 DAT, while the latter had a maximum phytotoxicity percentage of 88.8%. The differences observed between imazethapyr + imazapic and imazapyr + imazapic can be associated to the components of both mixtures, since imazapyr (525 g kg^{-1} of i.a.) + imazapic (175 g kg^{-1} of i.a.), besides presenting a higher concentration of imazapic in its formula, also has the imazapyr active compound, substituting imazethapyr, found in the imazethapyr mixture (75 g L^{-1} of i.a.) + imazapic (25 g L^{-1} of i.a.). Corroborating the results found in this paper, Galon et al. (2014b) and Santos et al. (2014) also observed a higher activity in the mixture of imazapyr + imazapic when compared to imazethapyr + imazapic when applying on different species of plants, and that is attributed to the components of both mixtures, as previously explained. The different response of the wheat cultivars to the injury caused by the tested treatments can, according to Santos et al. (2014) be associated to factors such as the physical-chemical characteristics of each herbicide, the ones inherent to each cultivar and the dose of the products.

The ryegrass control presented a variation between the tested treatments in the different times of evaluations, and in some cases according to the evaluated wheat cultivar (Tables 3 and 4). At 07 DAT, clomazone, followed by oxyfluorfen, presented better percentages of ryegrass control without differing among the cultivars, on average, 96.3 and 88.3%, respectively (Table 3).

Table 3. Control (%) of ryegrass by applying herbicides and wheat cultivars. UFFS/Erechim/RS, 2012/13.

Treatments	Control (%)					
	7 DAT[1]		14 DAT		21 DAT	
	Quartzo	Pioneiro	Quartzo	Pioneiro	Quartzo	Pioneiro
Iodosulfuron	61.8 Db[2]	69.8 Ca	88.8 CDa	90.0 CDa	94.3 BCa	95.3 Ba
Imazethapyr + imazapic	65.0 CDa	60.5 CDa	93.0 BCa	91.0 Ca	100.0 Aa	100.0 Aa
Clomazone	100.0 Aa	92.5 ABa	96.3 Aba	94.5 ABCa	97.8 ABb	100.0 Aa
Imazapic + imazapyr	75.5 Ca	65.0 CDb	96.8 Aba	97.3 ABa	100.0 Aa	100.0 Aa
Propanil	9.3 Fa	11.0 Ea	4.8 Ga	6.0 Ga	6.0 Ea	2.8 Eb
Oxyfluorfen	88.3 Ba	88.3 Ba	63.5 Fb	85.0 DEa	84.8 Da	80.5 Db
Metsulfuron-methyl	0.0 Fa	0.0 Ea	0.0 Ga	0.0 Ha	0.0 Fa	0.0 Ea
2.4-D	0.0 Fa	0.0 Ea	0.0 Ga	0.0 Ha	0.0 Fa	0.0 Ea
Cyhalofop-p-buthyl	50.0 Ea	55.0 Da	83.8 DEa	81.8 Ea	91.0 Ca	85.8 Cb
Penoxsulam	57.5 DEa	56.3 Da	82.5 Ea	73.8 Fb	81.3 Da	81.8 Da
Pyroxsulam	68.8 CDa	69.3 Ca	89.8 Ca	92.5 BCa	96.8 Aba	98.3 Aba
Control weeded	100.0 Aa	100.0 Aa	100.0 Aa	100.0 Aa	100.0 Aa	100.0 Aa
Control infested	0.0 Fa	0.0 Ea	0.0 Ga	0.0 Ha	0.0 Fa	0.0 Ea
CV (%)	9.01		3.77		2.31	

Treatments	Control (%)			
	28 DAT		35 DAT	
	Quartzo	Pioneiro	Quartzo	Pioneiro
Iodosulfuron	96.0 Ba	97.5 Aa	92.5 ABCb	99.3 Aa
Imazethapyr + imazapic	100.0 Aa	100.0 Aa	99.0 Aba	96.0 Aba
Clomazone	96.5 Bb	100.0 Aa	80.0 CDa	82.5 Ca
Imazapic + imazapyr	100.0 Aa	100.0 Aa	100.0 Aa	100.0 Aa
Propanil	0.0 Fa	0.0 Ea	0.0 Ea	0.0 Ea
Oxyfluorfen	70.3 Db	81.8 Ca	70.3 Db	81.8 Ca
Metsulfuron-methyl	0.0 Fa	0.0 Ea	0.0 Ea	0.0 Ea
2.4-D	0.0 Fa	0.0 Ea	0.0 Ea	0.0 Ea
Cyhalofop-p-buthyl	93.0 Ca	85.0 Bb	86.5 BCa	85.0 Bca
Penoxsulam	30.3 Eb	32.0 Da	81.3 CDa	39.3 Db
Pyroxsulam	98.0 ABa	99.5 Aa	98.5 Aba	100.0 Aa
Control weeded	100.0 Aa	100.0 Aa	100.0 Aa	100.0 Aa
Control infested	0.0 Fa	0.0 Ea	0.0 Ea	0.0 Ea
CV (%)	1.91		9.56	

[1]DAT: days after treatment. [2] Averages followed by the same uppercase on column and lowercase on line at each time of evaluation, do not differ by Tukey test at 5% of probability.

However, clomazone caused high phytotoxicity to both wheat crops (Table 2), differently from what was observed for oxyfluoren, which presented crop injuries below 3%. Thus, it is possible to see that oxyfluorfen, a PROTOX inhibitor, has a potential to be used in the handling of ryegrass, especially for biotypes resistant to herbicides that inhibit EPSPs, ALS and ACCase, since it showed low phytotoxicity and control of weeds of 88,3% and persisted until the end of the cycle with values above 70%.

When analyzing the other evaluation times, it is possible to realize that the use of iodosulfuron imazethapyr + imazapic, imazapic + imazapyr and pyroxsulam presented elevated percentages of ryegrass control for both cultivars, respectively, with average control for the whole cycle of 95.5, 96.5, 98.9 and 97.9% (Tables 3 and 4). From those, it is emphasized that imazethapyr + imazapic, imazapic + imazapyr, as well as clomazone, presented high rates of phytotoxicity to wheat (Table 2), for the Quartzo and Pioneiro cultivars, while oxyfluorfen, iodosulfuron, cyalofop-p-buthyl and pyroxsulam presented a satisfactory control of ryegrass and good wheat selectivity. It is worth highlighting that, to be considered an efficient herbicide, it needs to present control of a certain weed above 80% (Oliveira et al., 2009). Therefore, all herbicides mentioned above presented a control index above 80%, especially starting from the 14 DAT.

Table 4 Control (%) of ryegrass by applying herbicides and wheat cultivars. UFFS/Erechim/RS, 2012/13.

Treatments	Control (%)					
	42 DAT[1]		Anthesis		Preharvest	
	Quartzo	Pioneiro	Quartzo	Pioneiro	Quartzo	Pioneiro
Iodosulfuron	97.2 Aa[2]	100.0 Aa	98.0 ABa	98.5 Aa	97.8 Aa	91.8 Ab
Imazethapyr + imazapic	98.5 Aa	100.0 Aa	93.8 ABCa	95.3 Aa	93.8 ABa	91.0 Aba
Clomazone	97.0 Aa	82.5 Bb	95.0 ABa	82.5 Bb	87.5 BCa	82.5 Bca
Imazapic + imazapyr	100.0 Aa	100.0 Aa	100.0 Aa	100.0 Aa	95.5 ABa	94.5 Aa
Propanil	0.0 Da	0.0 Ca	0.0 Ea	0.0 Da	0.0 Fa	0.0 Ea
Oxyfluorfen	70.3 Cb	81.8 Ba	70.3 Db	83.3 Ba	70.3 DEa	72.5 Da
Metsulfuron-methyl	0.0 Da	0.0 Ca	0.0 Ea	0.0 Da	0.0 Fa	0.0 Ea
2.4-D	0.0 Da	0.0 Ca	0.0 Ca	0.0 Da	0.0 Fa	0.0 Ea
Cyhalofop-p-buthyl	99.0 Aa	85.0 Bb	95.5 ABa	67.5 Cb	78.8 CDa	78.8 CDa
Penoxsulam	81.3 Ba	75.0 Cb	85.0 Cb	92.5 Aa	77.8 Da	77.0 CDa
Pyroxsulam	98.5 Aa	100.0 Aa	100.0 Aa	100.0 Aa	99.3 Aa	100.0 Aa
Control weeded	100.0 Aa	100.0 Aa	90.8 BCb	100.0 Aa	67.5 Eb	100.0 Aa
Control infested	0.0 Da	0.0 Ca	0.0 Ca	0.0 Da	0.0 Fa	0.0 Ea
CV (%)	3.17		6.34		6.92	

[1]DAT: days after treatment. [2] Averages followed by the same uppercase on column and lowercase on line at each time of evaluation, do not differ by Tukey test at 5% of probability.

Herbicides metsulfuron-methyl, 2,4-D and propanil in all evaluated times (07, 14, 21, 28, 35, 42 DAT, blossoming and pre-harvest) for both wheat cultivars did not differ in the control percentage compared to the infested control, indicating inefficiency for the control of ryegrass (Tables 3 and 4). However, it is worth mentioning that metsulfuron-methyl and 2,4-D are registered and recommended for the control of dicotyledonous weeds that infest wheat (Agrofit, 2015).

Vargas and Roman (2005), when evaluating the control of weeds infesting the winter cereals, saw that metsulfuron-methyl and 2,4-D were not efficient in the control of black oats and ryegrass, corroborating what we saw in the present paper. For iodosulfuron, the same authors saw an average control of 80, 70 and 85%, starting at 14 DAT, respectively, for black oats, white oats and ryegrass. Arduim et al. (2012), when working with the efficiency of pyroxsulam in the control of weeds in wheat, saw that it provided a control above 80% and it may, therefore, be indicated for the handling of weeds infesting the crops.

The results show that after 35 DAT the iodosulfuron, imazethapyr + imazapic, imazapic + imazapyr and pyroxsulam herbicides presented excellent controls of ryegrass, lasting until the wheat pre-harvest, and statistically were equal to the weeded control (Tables 3 and 4), being those the most recommended for the control of this weed.

When comparing the cultivars with each other for the control of ryegrass plants, statistical differences were not seen in all times evaluated when applying imazethapyr + imazapic, metsulfuron-methyl, 2,4-D and pyroxsulam (Tables 3 and 4). The same was not seen for the other herbicides, which differed in the control of ryegrass among the cultivars in at least one of the times (Tables 3 and 4). Cyhalofop-p-buthyl showed an intermediate efficiency on the ryegrass plants and variable between the wheat cultivars, controlling an average of 52,5; 82,8; 88,4; 89,0; 85,8; 92,0; 81,5 and 78,8%, respectively, at 07, 14, 21, 28, 35, 42 DAT, blossoming and pre-harvest (Tables 3 and 4). It is worth considering that cyhalofop-p-buthyl, even in control of more than 80% of the ryegrass population that infested the wheat, must be handled cautiously for this weed, because this species is very competitive with the crop and is also resistant to herbicides belonging to the action mechanisms that inhibit EPSPs, ALS and ACCase (Roman et al., 2004; Vargas et al., 2013). Bastiani et al. (2012), when evaluating the alternatives for the handling of ryegrass biotypes resistant and susceptible to glyphosate, saw that cyhalofop-p-buthyl presented 100% of control for the susceptible biotype and 89% for the resistant biotype.

This way, it is evident that, in most cases, the wheat cultivars present a different behavior regarding the response to the control of herbicides applied for the handling of the ryegrass that infests the wheat. For Balbinot Jr. et al. (2003), this fact occurs due to the morphological and physiological characteristics of each cultivar, which defines the capacity of competing with weeds for the resources available in the environment, especially light, and that by doing that, the control by herbicides is more efficient.

The results show that the number of cobs m^{-2} was influenced in a different way by the tested treatments and among the cultivars evaluated (Table 5). It was seen that the Quartzo cultivar presented the best results when applying iodosulfuron, being superior to the weeded control, which did not differ from metsulfuron-methyl, cyalofop-p-buthyl and pyroxsulam. Also for the Quartzo cultivar, the smaller number of cobs m^{-2} was seen when using imazapic+imazapyr, followed by clomazone.

For the Pioneiro cultivar, the greatest number of cobs m^{-2} was seen with the use of oxyfluorfen and 2,4-D, which did not differ from the weeded control (Table 5). The treatment with imazapic+imazapyr, as it happened with Quartzo, was the one that presented a smaller number of cobs m^{-2}, which is associated to the high phytotoxicity of this mixture to the crop, causing the death of the plants. The results show that, when comparing the cultivars to each other, they did not differ when using imazapic+imazapyr, propanil and the weeded control. Thus, it is possible to see that the cultivars respond differently to the treatments tested, indicating that genetics is an important factor for the handling of treatments.

Contrary to what was observed in the present research, Rodrigues et al., (2006), when studying the behavior of the herbicide Dicamba applied at different times and doses on the wheat cultivars (BR 23 and Embrapa 16), saw that in two agricultural years (1992 and 1993) the number of cobs was not affected by none of the treatments.

Table 5. Yield components of wheat cultivars depending on the application of herbicides. UFFS. Erechim/RS, 2012/13.

Treatments	Ears m^{-2}		Yield (kg ha^{-1})		Thousand grain weight (g)	
	Quartzo	Pioneiro	Quartzo	Pioneiro	Quartzo	Pioneiro
Iodosulfuron	920.0 Aa	584.0 EFb	2583.1 Ab	3343.2 Aa	31.1 ABCb	32.5 Aa
Imazethapyr + imazapic	487.5 Eb	676.0 BCa	864.2 Ib	1019.1 Ia	29.6 CDa	29.7 CDEa
Clomazone	407.2 Fb	582.7 EFa	1160.6 Hb	2964.4 Ca	29.1 Da	29.1 Ea
Imazapic + imazapyr	0.0 Ga	0.0 Ga	0.0 La	0.0 Ja	0.0 Ea	0.0 Fa
Propanil	640.0 Ca	629.8 CDEa	2168.4 DEa	1926.1 Gb	31.8 Aba	32.1 Aa
Oxyfluorfen	650.0 Cb	736.0 Aa	2105.9 EFb	2976.8 BCa	32.1 Aa	32.2 Aa
Metsulfuron-methyl	767.7 Ba	662.7 BCDb	2030.2 Fb	2670.4 Da	30.3 BCDa	30.1 BCDa
2.4-D	486.0 Eb	696.0 ABa	1871.8 Ga	1511.7 Hb	31.9 Aba	30.2 BCDEb
Cyalofop-p-buthyl	766.3 Ba	658.0 BCDb	2351.1 Bb	2493.2 Ea	30.2 BCDa	31.0 ABCDa
Penoxsulam	557.0 Db	608.0 Dea	2259.0 Cb	2432.6 Ea	29.4 CDb	31.7 ABa
Pyroxsulam	776.0 Ba	534.4 Fb	2253.9 CDb	3059.0 Ba	31.9 Aba	29.4 DEb
Control weeded	722.3 Ba	734.5 Aa	2420.7 Ba	2263.0 Fb	31.3 ABCb	32.8 Aa
Control infested	578.0 Db	630.0 CDEa	505.9 Jb	1847.1 Ga	30.8 ABCDa	31.5 ABCa
CV (%)	4.10		1.88		2.71	

[1] Averages followed by the same uppercase on column and lowercase on line, do not differ by Tukey test at 5% of probability.

The productivity of grains of wheat cultivars was influenced by the treatment applied, and it was seen that, for Quartzo, the best results were in the treatments with the application of iodosulfuron, followed by cyalofop-p-buthyl and weeded control, those being around 80% superior to the infested control, which presented lower productivity, with the exception of imazapic+imazapyr that did not show productivity (Table 5) for having caused the death of the plants. For Pioneiro cultivar, the best responses for grains productivity were verified when applying iodosulfuron, followed by oxyfluorfen and pyroxsulam, 60% superior to the treatment with 2,4-D and imazethapyr + imazapic that, with the exception of imazapic + imazapyr, presented the lower productivities. Between the cultivars, in general, Pioneiro presented better productivity results of grains in face of the treatments tested.

The iodosulfuron, propanil, oxyfluorfen, 2,4-D and pyroxsulam herbicides, when evaluated on the Quartzo cultivar, did not differ from the weeded and infested controls for the variable of 1,000 grains (Table 5). For the Pioneiro cultivar, iodosulfuron, propanil, oxyfluorfen, cyalofop-p-buthyl and penoxsulam did not differ statistically from the two controls. Among the cultivars, it was observed that Pioneiro presents a greater mass - of 1,000 grains - than Quartzo. When evaluating the three variables (number of cops m^{-2}, grains productivity and mass of 1000 grains) it is realized, in general, that the Pioneiro cultivar presented better response when compared to Quartzo when applying treatments. This fact is probably associated to the genetic differences that exist among them, as reported previously.

It was observed that a number of sterile grains per cob of wheat was higher in the infested control, being equivalent to treatments with the application of clomazone, for cultivar Quartzo, and iodosulfuron for Pioneiro cultivar; the clomazone and both controls were statistically equivalent (Table 6). In general, the treatment the presented the smallest amount of sterile grains was pyroxsulam for both tested cultivars. It is highlighted that imazapic + imazapyr caused the death of wheat plants and, therefore, did not present a number of sterile grains nor the number of full grains. 2,4-D promoted a smaller number of sterile grains for both tested cultivars. The other treatments presented intermediate behaviors.

The results showed that the number of full grains per cob of Quartzo cultivar was higher when using oxyfluorfen, followed by iodosulfuron, clomazone and penoxsualm

(Table 6). The treatments with cyhalofop-p-buthyl and pyroxsulam presented a higher number of full grains compared to the other treatments when being applied on the Pioneiro cultivar. Galon et al. (2014), when evaluating the influence of herbicides on the grains yield components in barley crops, also saw a differentiation between the herbicides treatments and the genotypes tested (MN 610 and Crioula). Petter et al. (2011) observed a reduction in the productivity of grains when evaluating the application of different herbicides for the handling of weeds that infest rice. According to Dal Magro et al. (2006), when applying imazethapyr + imazapic on the rice crops IRGA 417, BR-IRGA 410, BRS Pelotas and Qualimax 1, observed a high phytotoxic effect on the crop, affecting negatively the yield of the rice and, consequently, the productivity of grains. On the other hand, Santos et al. (200), when working with propanil, fenoxaprop-ethyl, fenoxaprop-p-ethyl, oxadiaxon and the mixtures composed of propanil + molinate and propanil + 4,4-D, in the control of weeds, saw that the weight of one thousand grains of rice was not influenced by the herbicides applied or by the infestation of the weeds.

Tabela 6. Yield components of wheat cultivars depending on the application of herbicides. UFFS, Erechim/RS. 2012/13.

Treatments	Number of sterile grains		Number of filled grains	
	Quartzo	Pioneiro	Quartzo	Pioneiro
Iodosulfuron	12.7 Ba	12.5 ABa	40.0 Ba	39.4 Ba
Imazethapyr + imazapic	11.9 BCa	10.6 Db	34.5 Db	36.8 Ca
Clomazone	12.8 ABa	12.2 ABCb	40.4 Ba	33.8 Db
Imazapic + imazapyr	0.0 Ea	0.0 Fa	0.0 Ea	0.0 Ea
Propanil	11.2 CDa	10.7 Da	35.3 Db	38.6 BCa
Oxyfluorfen	11.8 BCa	11.4 CDa	44.4 Aa	36.9 Cb
Metsulfuron-methyl	11.1 CDa	11.6 BCDa	34.2 Da	34.0 Da
2.4-D	10.7 Da	10.8 Da	39.2 BCa	39.6 Ba
Cyhalofop-p-buthyl	12.2 BCa	10.7 Db	39.4 BCb	40.6 ABa
Penoxsulam	12.4 Ba	10.5 DEb	40.5 Ba	33.2 Db
Pyroxsulam	11.8 BCa	9.5 Eb	34.3 Db	42.2 Aa
Control weeded	12.3 Bb	13.2 Aa	37.7 Ca	36.8 Ca
Control infested	13.8 Aa	13.2 Aa	37.5 Cb	39.3 Ba
CV (%)	4.12		2.47	

[1] Averages followed by the same uppercase on column and lowercase on line, do not differ by Tukey test at 5% of probability.

The use of herbicides for the control of weeds in crops, besides having an environmental impact that can harm the agroecosystems, can interfere directly and/or indirectly in the growth and development of plants (Das et al., 2003; Rizzardi et al., 2003). For wheat, there is a lack of papers that have evaluated the phytotoxicity and the effects of the herbicides on the crop grains yield components. Ardium et al. (2012), when evaluating only the control of weeds that infect two wheat cultivars, with different herbicides and doses, saw that iodosulfuron and pyroxsulam presented an efficiency above 80%. Ferreira et al. (2003) and Dal Magro et al. (2006), when evaluating the effect of herbicides on the grains yield components and growth of the rice crop, saw their negative effect under these variables. These results are in accordance with the ones found in this study, that is, to control the weeds that infect the wheat, we need to differentiate the control according to the treatment used, as well as regarding the phytotoxicity to the crop and the effect they have on the grains yield components.

Conclusions

Imazethapyr + imazapic, clomazone and imazapic + imazapyr presented the greatest phytotoxicity on the wheat crops Quartzo and Pioneiro. Iodosulfuron, imazethapyr + imazapic, clomazone, imazapic + imazapyr and pyroxsulam showed to be the best controls for ryegrass. The iodosulfuron herbicide presented lower influence on the components of wheat grains yield when compared to the other herbicides applied on the Quartzo and Pioneiro cultivars.

Acknowledgements

The authors thank the CNPq and FAPERGS for the granting of financial assistance for the research (processes no. 482144/2012-2/CNPq and 12/2265-3/FAPERGS) and for the granted scholarships.

References

ABITrigo - Associação Brasileira da Indústria do Trigo. **Comparativo da estimativa aparente de moagem industrial de trigo**. São Paulo: Abitrigo, 2012. 5p.

Agostinetto, D.; Dal Magro, T.; Galon, L.; Moraes, P.V.D.; Tironi, S.P. Respostas de cultivares de soja transgênica e controle de plantas daninhas em função de épocas de aplicação e formulações de glyphosate. **Planta Daninha**, v.27, n.4, p.739-746, 2009.

Arduim, G.S.; Rubin, R.; Manzoni, C.G.; Daltro, F.; Neves, R.; Fadin, D.; Celmer, A. Eficiência do herbicida pyroxsulam no controle de diferentes plantas daninha na cultura do trigo (*Triticum aestivum* L.). In: Congresso Brasileiro da Ciência das Plantas Daninhas, 28., 2012, Campo Grande. **Resumos…** Londrina: SBCPD, 2012. p. 189-193. CD-ROM.

Balbinot Jr., A.A.; Fleck, N.G.; Menezes, V.G.; Agostinetto, D. Competitividade de cultivares de arroz irrigado com cultivar simuladora de arroz-vermelho. **Pesquisa Agropecuária Brasileira**, v.38, n.1, p.53-59, 2003.

Bastiani, M.O.; Galon, L.; Guimarães, S.; Lima, A.M.; Burg, G.M.; Belarmino, G.M.; Zandoná, R.R. Alternativas para o controle de azevém resistente ao glyphosate na fronteira oeste do rio grande do sul. In: Congresso Brasileiro da Ciência das Plantas Daninhas, 28., 2012, Campo Grande. **Resumos…** Londrina: SBCPD, 2012. p. 28-32. CD-ROM.

BRASIL. Ministério da Agricultura e Pecuária. Agrofit. Disponível em: <www.agricultura.gov.br>. Acesso em: 20 de ago. 2015.

Christoffoleti, P.J.; Borges, A.; Nicolai, M.; Carvalho, S.J.P.; López-Ovejero, R.F.; Monquero, P.A. Carfentrazone-ethyl aplicado em pós-emergência para o controle de *Ipomoea* spp. e *Commelina benghalensis* na cultura da cana-de-açúcar. **Planta Daninha**, v.24, n.1, p.83-90, 2006.

Companhia Nacional de Abastecimento - Conab. Trigo - Brasil. **Série histórica de: área, produtividade e produção**. Disponível em: <http://www.conab.gov.br/conteudos.php?>. Acesso em: 25 de maio 2015.

Costa, L.O.; Rizzardi, M.A. Resistance of *Raphanus raphanistrum* to the herbicide metsulfuron-methyl. **Planta Daninha**, v.32, n.1, p.181-187, 2014.

Dal Magro, T.; Agostinetto, D.; Pinto, J.J.O.; Galon, L.; Rezende, A.L. Efeito de deriva simulada de herbicida inibidor de ALS nos componentes da produtividade do arroz irrigado. **Planta Daninha**, v. 24, n. 4, p. 805-812, 2006.

Das, A.C.; Debnath, A.; Mukherjee, D. Effect of the herbicides oxadiazon and oxyfluorfen on phosphates solubilizing microorganisms and their persistence in rice fields. **Chemosphere**, v.53, n.5, p.217-221, 2003.

Embrapa - Empresa brasileira de pesquisa agropecuária. Centro Nacional de Pesquisa Agropecuária de Solos (Brasília, DF). Sistema brasileiro de classificação de solos. Brasília:

Embrapa Produção de Informação; Brasília, DF: Embrapa Solos, 2013. 154p.

Ferreira, E.A.; Santos, J.B.; Silva, A.A.; Ventrella, M.C.; Barbosa, M.H.P.; Procópio, S.O.; Rebello, V.P.A. Sensibilidade de cultivares de cana-de-açúcar à mistura trifloxysulfuron-sodium + ametryn. **Planta Daninha**, v.23, n.1, p.93-99, 2005.

Ferreira, F.B. **Resposta do arroz irrigado (*Oryza sativa*) a subdoses de glyphosate e butroxydim simulando efeito de deriva**. 2003. 52 f. Dissertação (Mestrado em Fitossanidade) – Universidade Federal de Pelotas, Pelotas, 2003.

Galon, L.; Ferreira, E.A.; Ferreira, F.A.; Silva, A.A.; Barbosa, M.H.P.; Reis, M.R. et al. Influência de herbicidas na qualidade da matéria-prima de genótipos de cana-de-açúcar. **Planta Daninha**, v.27, n.3, p. 555-562, 2009.

Galon, L.; Forte, C.T.; Kujawiski, R.; Radunz, A.L.; David, F.A.; Perin, G.F. et al. Eficácia e fitotoxicidade de herbicidas aplicados para o manejo de plantas daninhas em cevada. **Revista Brasileira de Herbicidas**, v.13, n.2, p.105-116, 2014a.

Galon, L.; Lima, A.M.; Guimarães, S.; Belarmino, J.G.; Burg, G.M.; Concenço, G. et al. Potential of plant species for bioremediation of soils applied with imidazolinone herbicides. **Planta Daninha**, v.32, n.4, p. 719-726, 2014b.

Galon, L.; Tironi, S.P.; Ferreira, E.A.; Vargas, L.; Silva, A.A. Manejo de plantas daninhas em cereais de inverno. In: SANTOS, H.P. et al. (Editores). **Sistemas de produção para cereais de inverno sob plantio direto no Sul do Brasil**. Passo Fundo: Embrapa Trigo, 2010. Cap.9, p.255-316.

Kissmann, K.G.; Groth, D. **Plantas infestantes e nocivas**. 2 ed. São Paulo: BASF, 1997. Tomo II. 978 p.

Lamego, F.P.; Ruchel, Q.; Kaspary, T.E.; Gallon, M.; Basso, C.J.; Santi, A.L. Habilidade competitiva de cultivares de trigo com plantas daninhas. **Planta Daninha**, v.31, n.3, p.521-531, 2013.

Oliveira, A.R., Freitas, S.P.; Vieira, H.D. Controle de *Commelina benghalensis*, *C. erecta*, *Tripogandra diuretica* na cultura do café. **Planta Daninha**, v.27, n.4, p.823-830, 2009.

Paula, J.M.; Vargas, L.; Agostinetto, D.; Nohatto, M.A. Manejo de *Conyza bonariensis* resistente ao herbicida glyphosate. **Planta Daninha**, v.29, n.1, p.217-227, 2011.

Petter, F.A.; Zuffo, A.M; Pacheco, L.P. Seletividade de herbicidas inibidores de als diferentes estádios de desenvolvimento do arroz de terras altas. **Pesquisa Agropecuária Tropical**, v. 41, n. 3, p. 408-414, 2011.

Pinto, J.J.O.; Galon, L.; Dal Magro, T.; Procópio, S.O.; Concenço, G.; Pinho, C.F. et al. Controle de capim-Arroz (*Echinochloa* spp.) em função de métodos de manejo na cultura do arroz irrigado**. Planta Daninha**, v.26, n.4, p.767-777, 2008.

Rigoli, R.P.; Agostinetto, D.; Vaz da Silva, J.M.B.; Fontana, L.C.; Vargas, L. Potencial competitivo de cultivares de trigo em função do tempo de emergência. **Planta Daninha**, v.27, n.1, p.41-47, 2009.

Rizzardi, M.A.; Fleck, N.G.; Agostinetto, D.; Balbinot Jr. A.A. Ação de herbicidas sobre mecanismos de defesa das plantas aos patógenos. **Ciência Rural**, v.33, n.5, p.957-965, 2003.

Rodrigues, O.; Marchese, J.A.; Vargas, L.; Velloso, J.A.O.; Rodrigues, R.C.S. Efeito da aplicação de herbicida hormonal em diferentes estádios de desenvolvimento de trigo (*Triticum aestivum* L. Cvs. Embrapa 16 e BR 23). **Revista Brasileira de Herbicidas**, v.5, n.1, p.19-29, 2006.

Rolas - Rede oficial de laboratórios de análise de solo e de tecido vegetal. **Manual de adubação e calagem para os estados do Rio Grande do Sul e Santa Catarina**. 10.ed. Porto

Alegre: Sociedade Brasileira de Ciência do Solo, 2004. 400p.

Roman, E.S.; Vargas, L.; Rizzardi, M.A.; Mattei, R.W. Resistência de azevém (*Lolium multiflorum*) ao herbicida glyphosate. **Planta Daninha**, v.22, n.2, p.301-306, 2004.

Santos, F.J.; Pitombeira, J.B.; Pinho, J.L.N.; Melo, F.O. Controle químico de plantas daninhas na cultura do arroz irrigado no estado do Ceará. **Planta Daninha**, v.18, n.1, p.29-37, 2000.

Santos, L.O.; Pinto, J.J.O.; Piveta, L.B.; Noldin, J.A.; Galon, L.; Concenço, G. Carryover effect of imidazolinone herbicides for crops following rice. **American Journal of Plant Sciences**, v.5, n.8, p.1049-1058, 2014.

SBCPD - Sociedade Brasileira da Ciência das Plantas Daninhas. **Procedimentos para instalação, avaliação e análise de experimentos com herbicidas**. Londrina: 1995. 42 p.

Scremin, A.P.; Kemerich, P.D. Impactos ambientais em propriedade rural de atividade mista. **Disciplinarum Scientia.** Série Ciências Naturais e Tecnológicas, v.11, n.1, p.126-148, 2010.

Vargas, L.; Fraga, D.S.; Agostinetto, D.; Mariani, F.; Duarte, T.V.; Silva, B.M. Dose-response curves of *Lolium multiflorum* biotypes resistant and susceptible to clethodim. **Planta Daninha**, v.31, n.4, p.887-892, 2013.

Vargas, L.; Roman, E.S. Seletividade e eficiência de herbicidas em cereais de inverno. **Revista Brasileira de Herbicidas**, v.4, n.3, p.1-10, 2005.