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Alternative control of ryegrass biotypes resistants to clethodim[1]

Controle alternativo de biótipos de azevém resistentes ao clethodim

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Abstract - Ryegrass is an annual cycle weed, present in winter crops, orchards and vineyards of southern Brazil. The species is typically controlled by the herbicide clethodim. However, continued use of this product selected resistant biotypes. Thus, the objective of this research was to evaluate the response of ryegrass populations resistant to clethodim to the application of herbicides of different mechanisms of action, and propose chemical control alternatives. An experiment was carried out in the Brazilian city of Coqueiros do Sul, in a randomized block design with three replications. The treatments assessed were: nicosulfuron (60 and 120 g a.i. ha^{-1}), iodosulfuron-methyl (6 and 12 g a.i. ha^{-1}), paraquat (400 and 800 g a.i. ha^{-1}), ammonium-glufosinate (600 and 1200 g a.i. ha^{-1}), clomazone (750 and 1500 g a.i. ha^{-1}), tembotrione (100 and 200 g a.i. ha^{-1}), clethodim (144 and 288 g a.i. ha^{-1}), haloxyfop-methyl (60 and 120 g a.i. ha^{-1}) and a control without the application of a herbicide. Herbicides tembotrione, nicosulfuron, iodosulfuron-methyl, clomazone, clethodim and haloxyfop-methyl were not efficient to control ryegrass. However, only herbicides paraquat and ammonium-glufosinate caused weed control and may be used to control populations of ryegrass resistant to herbicide clethodim.
Keywords: resistance; chemical control; *Lolium multiflorum*; weeds

Resumo - O azevém é uma planta daninha de ciclo anual, presente em lavouras de inverno, em pomares e vinhedos da região Sul do Brasil. A espécie é normalmente controlada pelo herbicida clethodim, no entanto, o uso continuado desse produto selecionou biótipos resistentes. Diante disso, o objetivo desta pesquisa foi avaliar a resposta de populações de azevém resistentes ao clethodim a aplicação de herbicidas de diferentes mecanismos de ação, e propor alternativas de controle químico. Um experimento foi realizado em Coqueiros do Sul, no delineamento de blocos ao acaso com três repetições. Os tratamentos avaliados foram: nicosulfuron (60 e 120 g i.a.ha^{-1}), iodosulfuron-metílico (6 e 12 g i.a.ha^{-1}), paraquat (400 e 800 g i.a. ha^{-1}), amônio-glufosinato (600 e 1200 g i.a. ha^{-1}), clomazone (750 e 1500 g i.a. ha^{-1}), tembotrione (100 e 200 g i.a. ha^{-1}), clethodim (144 e 288 g i.a. ha^{-1}), haloxifop-methyl (60 e 120 g i.a. ha^{-1}) e uma testemunha sem aplicação de herbicida. Os herbicidas tembotrione, nicosulfuron, iodosulfuron-metílico, clomazone, clethodim e haloxifop-methyl não foram eficientes no controle de azevém. Todavia, somente os herbicidas paraquat e amônio-glufosinato causaram o controle da planta daninha e podem ser utilizados no controle de populações de azevém resistentes ao herbicida clethodim.
Palavras-chaves: resistência; controle químico; *Lolium multiflorum*; planta daninha

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Introduction

The evolution of weed resistance to herbicides inhibitors of Acetyl-CoA carboxylase (ACCase) has been a threat to the efficient control of Poaceae species in agricultural systems. ACCase inhibitors were launched in the market in late 1970s and since then 46 species of weeds resistant to these herbicides have been recorded (Shaner, 2014; Heap, 2015). Among the resistant Poaceae, ryegrass (*L. multiflorum*), identified as resistant for the first time in 1987 in the United States, has great importance in southern Brazil, and after the record of the first case of resistant ryegrass, cases have been reported in Argentina, Chile, Denmark, France, Italy and Brazil. In Brazil, the cases were confirmed in 2010 in the state of Rio Grande do Sul (Heap, 2015).

In no-tillage systems or orchards, control of ryegrass has been typically accomplished with the application of non-selective herbicides and glyphosate is the most used in different growth stages of this species, but its indiscriminate use has selected biotypes resistant to this molecule (Roman et al., 2004). Therefore, the control of glyphosate-resistant biotypes began to be used as an alternative grass herbicide from the group of inhibitors of Acetyl-CoA carboxylase (ACCase). In recent seasons, difficulty in controlling ryegrass in wheat and maize crops with ACCase-inhibitor herbicides has been noted, suggesting the possibility of resistance. Currently, among the species resistant to ACCase-inhibiting herbicides, *Lolium multiflorum* is the species with the highest resistance records (Heap, 2015).

Still, resistant biotypes control measures need to be adopted and may be carried out by applying herbicide with a distinct mechanism of action. The use of herbicides with different mechanisms of action should be recommended in the management of resistant weeds (Johnson and Bibson, 2006; Vargas et al., 2009). To control clethodim-resistant ryegrass, the application of paraquat and sulfometuron in postemergence, and triflurarina, S-metolachlor and pyroxasulfone in preemergence is an effective alternative control (Owen et al., 2012).

Knowledge and indication of alternative herbicides to control these biotypes are important for the implementation of integrated management practices of that weed. The hypotheses for this study were that the populations of ryegrass resistant to the herbicide clethodim are controlled by herbicides with other mechanisms of action. Thus, the aim of this study was to investigate the clethodim-resistant ryegrass populations response to herbicides of different mechanisms of action and propose chemical control alternatives.

Material and Methods

The experiment was conducted in an agriculture area located in the Brazilian municipality of Coqueiros do Sul, RS (geographic coordinates S 28º11'13'' W 52º44'34'') from July to August 2013, where there was a history of successive applications of herbicide clethodim and control failures were reported in the year before the experiment, which was later confirmed from experiments performed in a greenhouse (Schneider et al., 2014).

The experimental design was randomized blocks with three replications and each experimental unit occupied a 6 m² (3 x 2) area, disregarding 0.5 m as a border. The treatments consisted of herbicides with different mechanisms of action (Table 1), being applied in their commercial dose recorded (1x) and twice the dose (2x).

Herbicides application occurred on 07/05/2013 when ryegrass plants had 5 to 6 tillers. Environmental conditions at the time of application were: temperature 23.4 °C and relative humidity of 79%. Spraying was performed using a knapsack sprayer pressurized with CO_2, equipped with fan-type nozzles 110.015, distributing a spray mix volume equivalent to 150 L ha^{-1}.

Table 1. Mechanism of action, active ingredient, commercial product and dose of herbicides used. Coqueiros do Sul, RS, 2013.

Mechanism of Action	Active Ingredient	Trade Name	Rate g a.i. ha^{-1}
ALS Inhibitor	nicosulfuron	Sanson®	60
	iodosulfuron-methyl	Hussar®	6
Photosysten I Inhibitor	paraquat	Gramoxone®	400
Glutamine Synthetase Inhibitor	amônio-glufosinate	Finale®	600
Carotenoid Biosynthesis Inhibitor	clomazone	Gamit®	750
	tembotrione	Soberan®	100
ACCase Inhibitor	clethodim	Select®	144
	haloxifop-methyl	Verdict®	60

Mineral oil was added to herbicides Hussar (0.3% v/v), Finale (0,2% v/v), Soberam (1 L/ha), Select (0,5% v/v) and Verdict (0.5% v/v).

The variables analyzed were control at 14, 21 and 28 DAT (days after the herbicide treatment). The data were analyzed for normality and homoscedasticity, studying the need for their transformation and subsequently they were subjected to an analysis of variance ($p \geq 0.05$). In case of statistical significance, means were compared by Duncan's test ($p \geq 0.05$).

Results and Discussion

The Shapiro-Wilk test demonstrated that the data transformation was not required. There were differences of control of the ryegrass population among the herbicides tested. In all the evaluations performed (14, 21 and 28 DAT), only the application of two times the dose of paraquat provided 90% or greater control (Table 2). Additionally, paraquat at the dose recorded at 14 and 21 DAT and ammonium-glufosinate at twice the dose in all assessments provided control levels above 80%, which despite being less than ideal can be considered viable and therefore registered for control of resistant ryegrass (Mapa, 2011). Ammonium-glufosinate can be an alternative to control ryegrass in postemergence of maize, considering that there are genetically modified genotypes available in the market with this resistance trait to this herbicide.

The lesser control obtained by other herbicides (tembotrione, nicosulfuron, iodosulfuron-methyl, clomazone, clethodim and haloxyfop-methyl) is probably due to three factors: advanced plant development stage, traditional low efficiency of herbicides, and the fact that resistance was confirmed. Traditionally, clethodim herbicide easily controls ryegrass regardless of the vegetative stage and should have provided a satisfactory control. Glyphosate-resistant ryegrass populations were controlled by more than 90% with herbicides clethodim and haloxyfop-methyl and 100% control by ammonium-glufosinate and paraquat (Roman et al., 2004; Vargas et al., 2004).

Iodosulfuron-methyl and nicosulfuron have an herbicidal action on ryegrass, providing up to 100% control when applied in postemergence of wheat and maize crops, respectively in stages of 1 to 2 tillers (Santos, 2012; Moraes et al., 2013; Agrofit, 2014). However, in this work its efficiency was low, suggesting that there may be biotypes also resistant to this herbicide, since there are already reports of ryegrass resistant to iodosulfuron-methyl in Rio Grande do Sul (Table 2) (Heap, 2014).

The other treatments were tested in order to assess possible herbicides with alternative mechanisms of action on ryegrass, as in the case of clomazone and tembotrione, despite the known limitations, mainly due to the application stage. The fact that clomazone application was carried out in postemergence may be the cause for this herbicide lower efficiency, since it has higher efficiency when applied in preemergence (Table 2). Other preemergence herbicides indicated for control of *Lolium multiflorum* are alachlor, acetolachlor, trifluralin and pendimethalin (Agrofit, 2014). The use of herbicides with residual effects is an effective strategy recommended for managing resistant weeds, mainly because they have different mechanisms of action (Owen et al., 2011).

Table 2. Control (%) at 14, 21 and 28 days after application of treatments of biotypes of *Lolium multiflorum* with 5 to 6 tillers, suspected of resistance to clethodim in response to the application of different herbicides. Coqueiros do Sul, RS 2013.

Treatments	Rate g a.i. ha^{-1}	Control efficiency (%)		
		14 DAT	21 DAT	28 DAT
Check	-----	0 m[1]	0 l	0 j
Nicosulfuron 1x	60	15 g	20 h	26 gh
Nicosulfuron 2x	120	15 g	24 g	30 fg
Paraquat 1x	400	80 c	80 c	74 b
Paraquat 2x	800	90 a	90 a	91 a
Amônio-glufosinate 1x	600	60 d	50 e	65 c
Amônio-glufosinate 2x	1200	85 b	84 b	81 b
Iodosulfuron-methyl 1x	6	7 j	5 j	18 hj
Iodosulfuron-methyl 2x	12	15 g	15 i	13 i
Clomazone 1x	750	13 h	15 i	19 hi
Clomazone 2x	1500	20 f	25 g	28 g
Tembotrione 1x	100	5 l	0 l	1 j
Tembotrione 2x	200	9 i	0 l	2 j
Clethodim 1x	144	16 g	50 e	44 de
Clethodim 2x	288	21 e	60 d	51 d
Haloxifop-methyl 1x	60	10 i	25 g	30 fg
Haloxifop-methyl 2x	120	20 f	45 f	38 ef
C.V. (%)	-----	3,21	3,6	13,36

[1]Means followed by the same letter in the columns do not differ significantly by Duncan's test ($p \geq 0.05$).

Although weed control in preemergence of wheat and maize crops is carried out almost exclusively with glyphosate and clethodim, practices to prevent the emergence of new cases of resistance to these herbicides should be used, because they can in extreme cases derail the production of these crops. Therefore, concern about *Lolium multiflorum* control failures is relevant, and the results of this experiment indicate that control failures in areas treated with herbicide clethodim are due to resistance. It is recommended that farmers use control alternatives involving the implementation of alternative herbicides in order to mitigate the development of ryegrass resistance to clethodim and, moreover, the use of cultures with resistance to other herbicides together with crop rotation and herbicide mechanisms of action, with crops such as maize resistant to ammonium-glufosinate.

Conclusions

Herbicides nicosulfuron, iodosulfuron-methyl, clomazone, tembotrione and haloxyfop-methyl are not alternatives to control ryegrass resistant to the herbicide clethodim.

Paraquat and ammonium-glufosinate herbicides are effective alternatives to control ryegrass resistant to the herbicide clethodim.

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