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Herbicide association applied to control weeds in glyphosate-resistant soybean[1]

Associação de herbicidas aplicados para o controle de plantas daninhas em soja resistente ao glyphosate

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Abstract - In order to bypass cases of glyphosate-resistant weeds, it becomes necessary to use herbicides with other action mechanisms. The goal of this work was to evaluate the effectiveness and selectivity of herbicides with isolated or tank mix application for the management of soybean-infesting glyphosate-resistant weeds. Treatments were applied sequentially, during pre-emergence: clomazone (900 g ha^{-1} a.i.); flumioxazin (50 g ha^{-1} a.i.); diclosulam (35.02 g ha^{-1} a.i.); s-metolachlor (1152 g ha^{-1} a.i.); sulfometuron + chlorimuron-ethyl (18.75 + 18.75 g ha^{-1} a.i.); pendimethalin (1250 g ha^{-1} a.i.); sulfentrazone (250 g ha^{-1} a.i.); sulfentrazone + chlorimuron-ethyl (250 + 20 g ha^{-1} a.i.); imazethapyr + sulfentrazone (100+250 g ha^{-1} a.i.) and imazaquin (150 g ha^{-1} a.i.) and, during post-emergence, glyphosate was used over these treatments (1080 g ha^{-1} a.e.). During post-emergence, glyphosate was applied in an isolated manner (1080 g ha^{-1} a.e.) and, mixed in the sprayer tank with glyphosate (1080 g ha^{-1} a.e.), imazethapyr (100 g ha^{-1} a.i.), clethodim (96 g ha^{-1} a.i.) and chlorimuron-ethyl (20 g ha^{-1} a.i.), plus the infested and weeded control samples. The experimental area was infested with 75% of creeping signalgrass plants (*Urochloa plantaginea*) and 25% of summergrass (*Digitaria ciliaris*), at the average densities of 133 and 45 plants m^{-2}, respectively. At 14 and 21 DAT, the application of glyphosate + [sulfometuron + chlorimuron-ethyl] caused a 67 and 62% phytotoxicity to soybean, respectively. In order to control summergrass and creeping signalgrass, this very mixture presented an 88% index at 21 DAT, whereas control for the other treatments exceeded 91% during all evaluated periods. All the evaluated treatments caused over 91% control of both weeds, except for glyphosate + [sulfometuron + chlorimuron-ethyl]. The associations of herbicides to glyphosate caused weed control and were selective to soybean, except for sulfometuron + chlorimuron-ethyl, which presented lower control and high phytotoxicity. Some herbicides damaged the yield components of soybean, but only the sulfometuron + chlorimuron-ethyl mixture caused a reduction in grain productivity.
Keywords: *Digitaria ciliaris*; *Glycine max*; *Urochloa plantaginea*

Resumo - Para contornar os casos de plantas daninhas resistentes ao glyphosate torna-se necessário o uso de herbicidas com outros mecanizamos de ação. Objetivou-se com o trabalho avaliar a eficácia e a seletividade de herbicidas aplicados isolados ou em mistura de tanque para o

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manejo de plantas daninhas infestante da soja resistente ao glyphosate. Os tratamentos foram aplicados de forma sequencial, em pré-emergência: clomazone (900 g ha^{-1} i.a.); flumioxazin (50 g ha^{-1} i.a.); diclosulam (35,02 g ha^{-1} i.a.); s-metolachlor (1152 g ha^{-1} i.a.); sulfometuron + chlorimuron-ethyl (18,75 + 18,75 g ha^{-1} i.a.); pendimethalin (1250 g ha^{-1} i.a.); sulfentrazone (250 g ha^{-1} i.a.); sulfentrazone + chlorimuron-ethyl (250 + 20 g ha^{-1} i.a.); imazethapyr + sulfentrazone (100 + 250 g ha^{-1} i.a.) e imazaquin (150 g ha^{-1} i.a.) e em pós-emergência sobre esses mesmos tratamentos usou-se o glyphosate (1080 g ha^{-1} e.a.). Em pós-emergência aplicou-se de modo isolado o glyphosate (1080 g ha^{-1} e.a.) e misturados ao tanque do pulverizador com glyphosate (1080 g ha^{-1} e.a.), imazethapyr (100 g ha^{-1} i.a.), clethodim (96 g ha^{-1} i.a.) e chlorimuron-ethyl (20 g ha^{-1} i.a.), mais as testemunhas infestada e capinada. A área experimental estava infestada com uma porcentagem de 75% de plantas de papuã (*Urochloa plantaginea*) e 25% com plantas de milhã (*Digitaria ciliaris*), nas densidades médias de 133 e 45 plantas m^{-2}, respectivamente. Aos 14 e 21 dias após a aplicação dos tratamentos (DAT) a aplicação de glyphosate + [sulfometuron + chlorimuron-ethyl] ocasionou fitotoxicidade à soja de 67 e 62% respectivamente. Para o controle de milhã e papuã essa mesma mistura apresentou índice de 88% aos 21 DAT, sendo que o controle para os demais tratamentos ultrapassou os 91% em todas as épocas avaliadas. Todos os tratamentos avaliados ocasionaram controle das duas plantas daninhas maior que 91%, exceto o glyphosate + [sulfometuron + chlorimuron-ethyl]. As associações dos herbicidas ao glyphosate ocasionaram controle das plantas daninhas e foram seletivas a soja, com exceção do sulfometuron + chlorimuron-ethyl, que apresentou menor controle e elevada fitotoxicidade. Alguns herbicidas prejudicaram os componentes de rendimento da soja, porém somente a mistura de sulfometuron + chlorimuron-ethyl apresentou diminuição da produtividade de grãos.

Palavras-chaves: *Digitaria ciliaris*; *Glycine max*; *Urochloa plantaginea*

Introduction

Soybean crop (*Glycine max* (L.) Merrill) in Brazil occupied, in the 2015/16 crop, an area of 32.1 million hectares, presenting an average productivity of 2,998 kg ha^{-1} (Conab, 2016). Among the factors affecting soybean productivity, it is possible to highlight the interference of weeds that compete for the available resources, such as water, light and nutrients; this damages the growth and development of the crop, as well as, in many cases, impeding the harvesting process (Agostinetto et al., 2015) or even hosting pests and diseases.

In order to control the weeds infesting Roundup Ready® soybean, an indispensable practice, mainly in the no-tillage system, is the use of glyphosate, both for the desiccation of the plantation and for applications during the post-emergence of weeds or the crop. However, glyphosate does not present residual effects for a prolonged control of weeds; in addition, its frequent use may result in resistance or it may even hinder the management of tolerant weeds. In Brazil, 11 plant species were already registered as resistant to EPSP inhibitors, from the substituted glycines group (Heap, 2016), an action mechanism that glyphosate represents.

Among the weeds that present high competitive ability with soybean and interfere significantly in the quality and quantity of the grains produced from Northern to Southern Brazil, it is possible to highlight the species *Digitaria ciliaris* (summergrass/hairy crabgrass) and *Urochloa plantaginea* (creeping signalgrass). It is worth highlighting that, within the Digitaria genus, there are biotypes of sourgrass (*D. insularis*) that are resistant to EPSP and ACCase inhibitor herbicides (Agostinetto e Vargas, 2014), which limits their use to control the aforementioned species.

The main control method of these soybean-infesting weeds is the chemical one, with the application of herbicides from the chemical group of aryloxyphenoxypropionics and cyclohexadiones, above all (Dias et al., 2005; López-Ovejero et al., 2006). However, with the advent of glyphosate-resistant soybean, this herbicide started to be used repeatedly instead of ACCase and ALS inhibitors; this caused the appearance of resisting plant populations. Thus, the current goal is to evaluate the use of tank mixtures with glyphosate of herbicides belonging to other action mechanisms to manage weeds infesting soybean crop.

As a possible alternative to control problematic weeds, a good management method is the association of glyphosate with other herbicides, in order to guarantee a more effective control and prevent them to become resistant. The association of glyphosate with other herbicides such as diclosulam, chlorimuron-ethyl, imazethapyr, clomazone, ACCase inhibitors, among others, becomes indispensable to manage resistant weeds that infest soybean plantations and/or even to increase the control spectrum (Procópio et al., 2007; Melo et al., 2012; Maciel et al., 2009; Santos et al., 2016).

The association of glyphosate with sethoxydim, haloxyfop-methyl, fluazifop-p-butyl, fenoxaprop + clethodim, tepraloxydim proved to be viable alternatives to control EPSPs inhibitor-resistant sourgrass (D. insularis) (Melo et al., 2012). Some mixtures, such as the association of diclosulam and glyphosate, helps reducing the initial competitiveness of the infesting community, but does not exempt a complementary application, over an area with the species *U. ruziziensis* (Santos et al., 2016).

The importance of the association of different action mechanisms to control weeds has been considered a promising technique, with the goal to control a higher number of species (Vieira Júnior et al., 2015) and prevent the resistance of weeds to herbicide molecules (Owen and Zelaya, 2005).

The hypothesis of this research is that the association of herbicides with different action mechanisms in a tank mixture with glyphosate creates better control on weeds and does not interfere in the yield components of soybean.

The goal of this work was to evaluate the effectiveness and selectivity of herbicides with isolated or tank mix application for the management of soybean-infesting glyphosate-resistant weeds.

Material and Methods

The experiment was installed on the field in an experimental area of the Universidade Federal da Fronteira Sul (UFFS), Câmpus Erechim, Rio Grande do Sul state, between November 2015 and March 2016. Thirty days before soybean seeding, the vegetation composed by black oat was desiccated using the herbicides glyphosate + 2,4-D (1.080 + 1.209 g ha^{-1} a.e.) in order to sow the soybean cultivar ND 5445 IPRO with the no-tillage system. Fertilization in the sowing furrow was made using the 5-20-20 (N-P-K) formula, in the quantity of 276 kg ha^{-1}, according to soil analysis.

The experiment was installed in randomized block design with four replications. The herbicides used in the test were: glyphosate (Roundup Original, 360 g L^{-1} SL, Monsanto), clomazone (Gamit 360 CS, 360 g L^{-1}, FMC), flumioxazin (Flumyzin 500, 500 g kg^{-1} WG, Sumitomo), diclosulam (Spider 840 WG, 840 g kg^{-1}, WG, Dow Agrosciences), s-metolachlor (Dual Gold, 960 g L^{-1} EC, Syngenta), [sulfometuron + chlorimuron-ethyl] (Ligate 15 + 20 g kg^{-1} WG, DuPont), pendimentalin (Herbadox, 500 g L^{-1} SC, Basf), sulfentrazone (Boral 500 SC, 500 g L^{-1} SC, FMC), imazethapyr (Pivot, 100 g L^{-1} SL, Basf), clethodim (Poquer, 240 g L^{-1} EC, Adama), chlorimuron-ethyl (Classic, 250 g kg^{-1} WG, DuPont) and imazaquin (Scepter, 150 g L^{-1} SC, Basf). The used treatments and herbicide doses are described in Table 1, together with the application time.

Table 1. Treatments used in the experiment, respective doses and period of application to control weeds on soybean crop. UFFS. Erechim (RS), 2015/2016.

Treatments	Doses (g ha^{-1} a.i. or a.e.)
Infested control	-
Weeded control	-
Glyphosate[1]	1080
Glyphosate[1] + clomazone[2]	1080 + 900
Glyphosate[1] + flumioxazin[2]	1080 + 50
Glyphosate[1] + diclosulam[2]	1080 + 35.02
Glyphosate[1] + s-metolachlor[2]	1080 + 1152
Glyphosate[1] + [sulfometuron + chlorimuron-ethyl][2]	1080 + [1.5 + 2]
Glyphosate[1] + pendimentalin[2]	1080 + 1250
Glyphosate[1] + sulfentrazone[2]	1080 + 250
Glyphosate[1] + imazethapyr[1]	1080 + 100
Glyphosate[1] + clethodim[1]	1080 + 96
Glyphosate[1] + chlorimuron-ethyl[1]	1080 + 20
Glyphosate[1] + sulfentrazone[2] + chlorimuron-ethyl[2]	1080 + 250 + 20
Glyphosate[1] + imazethapyr[2] + sulfentrazone[2]	1080 + 100 + 250
Glyphosate[1] + imazaquin[2]	1080 + 150

[1] Application during the post-emergence of crop and weeds. [2] Application during the pre-emergence of crop and weeds.

Each experimental unit was characterized by a 15 m^2 (5 x 3 m) plot sown with 6 soybean rows, spaced 0.5 m apart, in a population of 10 to 12 plants m^{-1}. The experimental area was infested with 75% of creeping signalgrass plants (*Urochloa plantaginea*) and 25% of summergrass (*Digitaria ciliaris*), at the average densities of 133 and 45 plants m^{-2}, respectively. Herbicide application was performed with a CO_2 pressurized backpack precision sprayer, equipped with four DG 110.02 fan-type spraying nozzles, maintaining a constant pressure of 210 kPa and travel speed of 2.6 km h^{-1}, which provided a 150 L ha^{-1} flow of the herbicide mixture.

Conditions at the time of pre-emergence application were: cloudy sky, air temperature of 26.8°C, 68% air relative humidity, damp soil and winds at 1.8 to 4.0 km h^{-1}. During the post-emergence application, the sky was partially cloudy, the air temperature was 25.4°C, 65% air relative humidity, damp soil and winds at 1.3 to 3.6 km h^{-1}. At the time of post-emergence application, the crop presented 3 completely developed trefoils (V3 stage) and weeds with 2 to 3 leaves. Climate conditions during the experiment are exposed on Figure 1.

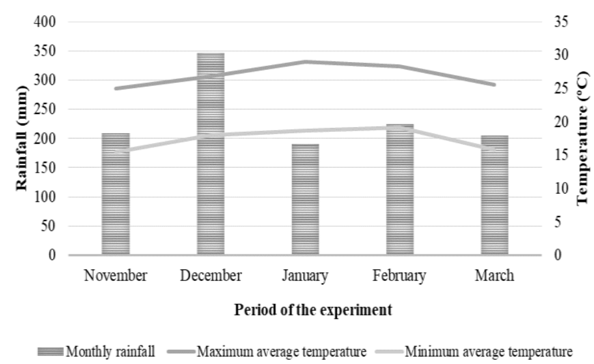

Figure 1. Monthly rainfall (mm), maximum and minimum average temperature (°C) during the period of the experiment. UFFS. Erechim (RS), 2015/2016.

The phytotoxicity caused by herbicides on the soybean cultivar ND 5445 IPRO was evaluated at 7, 14 and 21 after treatment application (DAT). Control evaluations of creeping signalgrass and summergrass were performed at 7, 14 and 21 DAT and during the pre-harvest (PH) of the crop. Percentage grades were assigned, where zero (0%) represented phytotoxicity absence to soybean, or with control absence on creeping signalgrass and/or summergrass and one hundred (100%) for the complete death of the crop or weeds (SBCPD, 1995).

The variables evaluated on 10 plants from each plot during pre-harvesting were: number of pods per plant (NPP) and number of beans per pod (BPP). Soybean harvesting was performed when the beans reached 16% humidity, in a usable area of 3.0 m^2 per experimental unit. In the end, the thousand kernel weight - TKW (g) was determined, counting 8 samples of 100 kernels each and weighing them on an analytical scale. As for the analyses, kernel humidity was adjusted to 13% and productivity data (PROD) were extracted for kg ha^{-1}.

Data were submitted to analysis of variance by F test and, if significant, the averages were submitted to the Scott-Knott test at $p \leq 0.05$.

Results and Discussion

For all the studied variables, it was possible to observe significant differences ($p \leq 0.05$) according to the application of the herbicides during pre- and/or post-emergence, or even in association with glyphosate (Tables 2, 3, 4, and 5).

Table 2. Phytotoxicity (%) for the soybean cultivar ND 5445 IPRO according to the application of herbicides during the pre- and/or post-emergence of the crop. UFFS. Erechim (RS), 2015/2016.

Treatments	Application Period	Phytotoxicity %		
		7 DAT	14 DAT	21 DAT
Infested control	-	0 e	0 d	0 e
Weeded control	-	0 e	0 d	0 e
Glyphosate	Post	3 c	0 d	0 e
Glyphosate + clomazone	Post + Pre	3 c	0 d	0 e
Glyphosate + flumioxazin	Post + Pre	2 d	3 c	4 d
Glyphosate + diclosulam	Post + Pre	3 c	7 b	9 b
Glyphosate + s-metolachlor	Post + Pre	3 c	4 c	0 e
Glyphosate + [sulfometeuron + chlorimuron-ethyl]	Post + Pre	0 e	67 a	62 a
Glyphosate + pendimethalin	Post + Pre	4 c	0 d	5 d
Glyphosate + sulfentrazone	Post + Pre	3 c	6 b	5 d
Glyphosate + imazethapyr	Post + Pre	6 b	5 b	6 e
Glyphosate + clethodim	Post	4 c	0 d	0 e
Glyphosate + chlorimuron-ethyl	Post	8 a	6 b	4 d
Glyphosate + (sulfentrazone + chlorimuron-ethyl)	Post + Pre	4 c	5 b	6 c
Glyphosate + (imazethapyr + sulfentrazone)	Post + Pre	3 c	4 c	0 e
Glyphosate + imazaquin	Post + Pre	2 d	4 c	5 d
CV (%)		30.57	22.93	18.67

Averages followed by the same lowercase letter in the column, in each evaluation period, do not different among themselves by the Scott-Knott test at $p<0.05$.

At 7 DAT, all treatments cause phytotoxicity on soybean according to the application of the herbicides, except for glyphosate + (sulfometeron + chlorimuron-ethyl) (Table 2). The highest phytotoxicity, in this first evaluation, was 8%, caused by the tank mix of glyphosate + chlorimuron-ethyl. Supporting this work, Maciel et al. (2009) also reported that the tank mix of glyphosate associated with chlorimuron-ethyl-ethyl, applied on soybean crop, resulted in phytotoxicity, with the highest values at 7 after the application of the herbicides for the cultivar Monsoy 7210RR (25.5 to 31.5%), followed by Monsoy 7979RR (19.5 to 25.5%) and CD 214RR (17.8 to 25.5%), and in lower intensity for BRS 245RR® (10 to 17.5%).

At 14 and 21 DAT, glyphosate + [sulfometeron + chlorimuron-ethyl] caused the highest phytotoxicities, namely 67 and 62%, respectively (Table 2). This high phytotoxicity degree is due to the fact that the commercial mixture composed by sulfometeron + chlorimuron-ethyl, with the commercial brand

Ligate®, is indicated to control annual monocots and dicots in soybean cultivars, identified as LIGATE™ STS™ (Du Pont, 2016) and registered in some countries, such as Argentina, for this purpose. This technology is still being studied in Brazil, and for this reason, this herbicide was applied to evaluate its effects on non-tolerant soybean cultivars, and to test its effectiveness in controlling weeds. Soybean plants that do not present tolerance to the sulfometuron + chlorimuron-ethyl mixture, mainly to sulfometuron, had severe injuries with the application of the herbicide; even at low doses of the product, phytotoxicity may vary from 74 to 96% at 37 days after application (Correia and Leite, 2012).

Table 3. Summergrass control (%) in soybean crop, according to the application of herbicides during pre- and post-emergence. UFFS. Erechim (RS), 2015/2016.

Treatments	Application Period	Summergrass control (%)			
		7 DAT	14 DAT	21 DAT	PH
Infested control sample	-	0 c	0 b	0 d	0 b
Weeded control sample	-	100 a	100 a	100 a	100 a
Glyphosate	Post	98 b	100 a	96 a	98 a
Glyphosate + clomazone	Post + Pre	100 a	100 a	96 a	97 a
Glyphosate + flumioxazin	Post + Pre	98 b	99 a	93 b	96 a
Glyphosate + diclosulam	Post + Pre	100 a	99 a	95 b	86 a
Glyphosate + s-metolachlor	Post + Pre	99 b	99 a	97 a	98 a
Glyphosate + (sulfometuron + chlorimuron-ethyl)	Post + Pre	100 a	100 a	88 c	87 a
Glyphosate + pendimethalin	Post + Pre	98 b	100 a	98 a	99 a
Glyphosate + sulfentrazone	Post + Pre	100 a	100 a	94 b	99 a
Glyphosate + imazethapyr	Post + Pre	98 b	100 a	99 a	100 a
Glyphosate + clethodim	Post	98 b	99 a	97 a	97 a
Glyphosate + chlorimuron-ethyl	Post	98 b	99 a	98 a	98 a
Glyphosate + (sulfentrazone + chlorimuron-ethyl)	Post + Pre	100 a	99 a	92 b	97 a
Glyphosate + (imazethapyr + sulfentrazone)	Post + Pre	100 a	99 a	97 a	96 a
Glyphosate + imazaquin	Post + Pre	100 a	99 a	93 b	93 a
CV (%)		0.68	0.93	2.75	7.02

Averages followed by the same lowercase letter in the column, in each evaluation period, do not different among themselves by the Scott-Knott test at $p<0.05$.

Both the herbicides that were applied during pre-emergence and during post-emergence, except for sulfometuron + chlorimuron-ethyl, did not present high phytotoxicity levels; the maximum level was 9% for all evaluated periods (Table 2). The recommended herbicide doses must be respected, since the combination of many herbicides with glyphosate may present a synergic effect and cause high phytotoxicity, as reported by Procópio et al. (2007) who, when using a mixture of chlorimuron-ethyl + glyphosate, observed 1 to 33% injuries to soybean RR plants; this variation depends on the dose that was used in the applications.

In the control evaluations performed at 7 and 14 DAT for both weed species, it was possible to observe more than 97% control, regardless of the applied herbicide, both for summergrass and creeping signalgrass (Tables 3 and 4). The application of glyphosate to control *U. plantaginea*, at the 960 g ha^{-1} dose, caused 88 to 100% control of plants, thus demonstrating high effectiveness of this herbicide over this weed (López-Ovejero et al., 2013).

Results demonstrated that only the application of glyphosate + (sulfometuron + chlorimuron-ethyl) presented an 88% control over creeping signalgrass and summergrass at 21 DAT (Tables 3 and 4), whereas all the other herbicide treatments presented more than 97% control in all evaluations. It is worth highlighting that in order to be considered effective, an herbicide must present more than

80% control over a determined weed (Oliveira et al., 2009). Thus, all the herbicide treatments tested in this study presented a control index above 80%, even from day 7 DAT. However, it is worth highlighting that determined weeds, even in small populations, may decrease drastically the productivity of soybean, as it is for creeping signalgrass and summergrass, which present high competitive ability in relation to the crop (Agostinetto et al., 2009; Agostinetto et al., 2013).

Table 4. Creeping signalgrass control (%) in soybean crop, according to the application of herbicides during pre- and post-emergence. UFFS. Erechim (RS), 2015/2016.

Treatments	Application Period	Creeping signalgrass control (%)			
		7 DAT	14 DAT	21 DAT	PH
Infested control sample	-	0 c	0 b	0 c	0 b
Weeded control sample	-	100 a	100 a	100 a	100 a
Glyphosate	Post	98 b	100 a	94 b	97 a
Glyphosate + clomazone	Post + Pre	100 a	99 a	91 b	95 a
Glyphosate + flumioxazin	Post + Pre	98 b	100 a	97 a	95 a
Glyphosate + diclosulam	Post + Pre	100 a	100 a	91 b	86 a
Glyphosate + s-metolachlor	Post + Pre	98 b	100 a	99 a	96 a
Glyphosate + (sulfometuron + chlorimuron-ethyl)	Post + Pre	100 a	99 a	88 b	85 a
Glyphosate + pendimethalin	Post + Pre	97 b	100 a	97 a	97 a
Glyphosate + sulfentrazone	Post + Pre	100 a	100 a	94 b	86 a
Glyphosate + imazethapyr	Post + Pre	98 b	100 a	99 a	99 a
Glyphosate + clethodim	Post	98 b	99 a	92 b	92 a
Glyphosate + chlorimuron-ethyl	Post	98 b	99 a	97 a	93 a
Glyphosate + (sulfentrazone + chlorimuron-ethyl)	Post + Pre	100 a	99 a	91 b	82 a
Glyphosate + (imazethapyr + sulfentrazone)	Post + Pre	100 a	99 a	96 a	94 a
Glyphosate + imazaquin	Post + Pre	99 a	99 a	92 b	93 a
CV (%)		0.79	1.07	3.01	11.48

Averages followed by the same lowercase letter in the column, in each evaluation period, do not different among themselves by the Scott-Knott test at $p<0.05$.

In the control evaluation of summergrass, performed during the pre-harvesting of soybean, it was possible to observe that glyphosate + diclosulam and glyphosate + (sulfometuron + chlorimuron-ethyl) reduced the control indices in relation to previous evaluations (Table 3). Treatments constituted by glyphosate + flumioxazin, glyphosate + diclosulam, glyphosate + s-metolachlor, glyphosate + (sulfometuron + chlorimuron-ethyl), glyphosate + sulfentrazone, glyphosate + clethodim, glyphosate + chlorimuron-ethyl, glyphosate + (sulfentrazone + chlorimuron-ethyl) and glyphosate + (imazethapyr + sulfentrazone), presented lower control over creeping signalgrass in the last evaluation period, when compared to the evaluations from day 7, 14 and 21 DAT (Table 4). The other treatments evaluated during the pre-harvesting soybean demonstrated differentiated controls according to the species onto which they were applied. Thus, it is evident that the control from a determined herbicide, either applied singularly or in tank mix, depends on the weed species in the area and on the product itself. The control reduction in some treatments evaluated on the pre-harvesting of soybean may be related to the high rainfall occurred in December (Figure 1), with possible herbicide leaching.

It was possible to observe that summergrass control, in all evaluation periods, when using treatments composed by glyphosate + clomazone, glyphosate + s-metolachlor and glyphosate + (imazethapyr + sulfentrazone) were the best, compared to the others (Table 3). As for creeping signalgrass control, in all evaluations (7, 14, 21 DAT and during pre-harvesting), the only treatment that was better than the others was glyphosate + (imazethapyr + sulfentrazone) (Table 4). Sulfentrazone has been already studied to control both monocots and dicots infesting RR soybean, presenting promising results for the management of Bidens pilosa and Commelina benghalensis, together with glyphosate (Osipe et al., 2008).

Treatments involving the application of isolated glyphosate in post-emergence, or glyphosate + diclosulam, glyphosate + pendimentalin, glyphosate + sulfentrazone, glyphosate + chlorimuron-ethyl, glyphosate + (sulfentrazone + chlorimuron-ethyl), glyphosate + (imazethapyr + sulfentrazone) and glyphosate + imazaquin presented the highest number of pods per plant (NPP), with no statistical differences from the weeded control sample (Table 5). Herbicides such as imazethapyr and chlorimuron-ethyl applied in post-emergence were already studied by Braz et al. (2010); they did not present any effect on NPP, supporting the results obtained in this work.

Table 5. Number of pods per plant (NPP), number of kernels per pod (NKP), thousand kernel weight in g (TKW) and productivity of the soybean cultivar ND 5445 IPRO (kg ha^{-1}) (PROD), according to the application of different herbicides during pre- and post-emergence. UFFS. Erechim (RS), 2015/2016.

Treatments	Application Period	NPP	NKP	TKW (g)	PROD (kg ha^{-1})
Infested control sample	-	16.63 d	2.36 b	158.35 b	696.94 c
Weeded control sample	-	34.50 a	2.40 b	172.97 a	2957.17 a
Glyphosate	Post	35.97 a	2.30 b	180.89 a	3280.30 a
Glyphosate + clomazone	Post + Pre	30.10 b	2.42 b	177.96 a	3248.99 a
Glyphosate + flumioxazin	Post + Pre	31.50 b	2.50 a	170.17 a	3212.21 a
Glyphosate + diclosulam	Post + Pre	34.13 a	2.44 b	165.02 b	2990.79 a
Glyphosate + s-metolachlor	Post + Pre	31.30 b	2.60 a	174.89 a	3371.02 a
Glyphosate + [sulfometuron + chlorimuron-ethyl]	Post + Pre	22.70 c	2.22 b	147.19 b	1108.82 b
Glyphosate + pendimethalin	Post + Pre	35.45 a	2.42 b	163.29 b	3356.81 a
Glyphosate + sulfentrazone	Post + Pre	33.27 a	2.47 b	173.22 a	3522.87 a
Glyphosate + imazethapyr	Post + Pre	30.97 b	2.67 a	166.59 b	3454.76 a
Glyphosate + clethodim	Post	31.90 b	2.35 b	171.76 a	3081.33 a
Glyphosate + chlorimuron-ethyl	Post	37.10 a	2.49 a	165.20 b	3177.22 a
Glyphosate + (sulfentrazone + chlorimuron-ethyl)	Post + Pre	35.53 a	2.61 a	182.27 a	3487.38 a
Glyphosate + (imazethapyr + sulfentrazone)	Post + Pre	34.01 a	2.58 a	170.17 a	3386.97 a
Glyphosate + imazaquin	Post + Pre	34.33 a	2.44 b	179.73 a	3187.05 a
CV (%)		5.42	6.21	6.74	8.62

Averages followed by the same lowercase letter in the column, in each evaluation period, do not different among themselves by the Scott-Knott test at $p<0.05$.

It was possible to observe a NPP reduction of approximately 34 and 50% with the application of glyphosate + (sulfometuron + chlorimuron-ethyl) and when soybean was maintained infested, compared to the weeded control sample, respectively. Braz et al. (2010) did not observe any NPP difference in the weeded or non-weeded control sample, probably because soybean sowing was performed after maize and the weed density was low.

NKP was higher in treatments with the application of glyphosate + flumioxazin, glyphosate + s-metolachlor, glyphosate + imazethapyr, glyphosate + chlorimuron-ethyl, glyphosate + (sulfentrazone + chlorimuron-ethyl) and glyphosate + (imazethapyr + sulfentrazone); it was even higher than the weeded sample (Table 5). Both the weeded and the infested control samples did not present significant differences in this variable. This is explained by the fact that it is a primary component related to the genetic characteristics and it is not very affected by the competition among weeds; also, the NKP demonstrated low variation even when herbicides are applied (Mundstock and Thomas, 2005; Silva et al., 2008).

The thousand-kernel weight (TKW), which is an important yield component, suffered variations according to the applied treatment (Table 5). Treatments involving the herbicides glyphosate + diclosulam, glyphosate + (sulfometuron + chlorimuron-ethyl), glyphosate + pendimenthalin, glyphosate + imazethapyr, glyphosate + chlorimuron-ethyl were statistically equal to the infested control sample, thus presenting lower TKW in relation to the other treatments. Unlike what was observed in this study, the use of diclosulam did not reduce the TKW in the work conducted by Santos et al., (2016). It is worth highlighting that it may happen according to the edaphoclimatic differences or even to the soybean cultivar where the herbicides to manage weeds are applied.

The TKW reduction with the application of some herbicides is directly connected to the other yield components (N and NKP), since these treatments caused an increase in at least one of these variables, with the exception of the application of glyphosate + [sulfometuron + chlorimuron-ethyl] (Table 5).

Only the treatment involving the application of glyphosate + [sulfometuron + chlorimuron-ethyl] presented lower productivity when compared to the other treatments; it was only higher than the infested control sample (Table 5). This occurred according to the high phytotoxicity that this very treatment caused to soybean (Table 2) and because of the lower control of creeping signalgrass and summergrass it occasioned (Tables 3 and 4). It is possible to highlight that the commercial mixture composed by sulfometuron + chlorimuron-ethyl is not recommended for all soybean cultivars; it is only recommended for the ones presenting tolerance to sulfonylureas, as specified before. The use of chlorimuron-ethyl associated to glyphosate in the post-emergence of soybean did not affect significantly the crop productivity (Maciel et al., 2009); these results support the ones found in this work.

Weed control with the use of herbicides incremented the grain productivity of soybean by 473% in relation to the infested control sample (Table 5). Thus, productivity data confirmed the prejudicial effect of weed competition in the crop yield (Table 5); this effect was already observed by other authors (Petter et al., 2007; Agostinetto et al., 2009; Schneider et al., 2014).

Results demonstrate that the best treatment taking into consideration the lowest phytotoxicity (Table 2), the best creeping signalgrass and summergrass control (Tables 3 and 4), and the best for not influencing negatively the yield components of soybean, was the application of glyphosate + (sulfentrazone + chlorimuron-ethyl) and glyphosate + (imazethapyr + sulfentrazone).

Conclusions

The mixture composed by glyphosate + (sulfometuron + chlorimuron-ethyl) presented the highest phytotoxicity to the soybean cultivar ND 5445 IPRO.

The application of glyphosate + clomazone, glyphosate + s-metolachlor and glyphosate + (imazethapyr + sulfentrazone) presented the best control for summergrass.

The use of glyphosate + (imazethapyr + sulfentrazone) demonstrated the highest control on creeping signalgrass.

Grain yield components, NPP, NKP, TKW and PROD from the soybean cultivar ND 5445 IPRO were not affected by the application of glyphosate + (sulfentrazone + chlorimuron-ethyl) and glyphosate + imazethapyr + sulfentrazone.

Weed control with the use of herbicides demonstrated an average increase of 473% in the productivity of soybean kernels.

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