Revista Brasileira de Herbicidas, v.14, n.2, p.117-127, abr./jun. 2015 (ISSN 2236-1065)
DOI: http://dx.doi.org/10.7824/rbh.v14i2.284 www.rbherbicidas.com.br

Effect of application time of sulfonylurea herbicides to control annual ryegrass in wheat crops[1]

Efeito da época de aplicação de herbicidas sulfonilureias no controle de azevém anual na cultura do trigo

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Abstract - The adoption of weed management practices is one of the main tools that can contribute to increased grain yield in wheat crops. This study has aimed to evaluate the efficiency of the chemical group of the sulfonylurea herbicides, alone and in combination, at different times of the application, on the productivity of wheat cultivars, and control of annual ryegrass (*Lolium multiflorum* L.). The design was randomized blocks with 5 repetitions. The treatments were arranged in a 4 x 2 x 2 factorial design consisting in applying metsulfuron-methyl and iodosulfuron-methyl, alone and in combination, and control, using two commercial cultivars of wheat (Quartzo and BRS Tangará) in two application periods, 21 and 30 days after application. Cultivars phytointoxication, the level of control of annual ryegrass and the performance of agronomic traits of wheat crops were evaluated. For the control of annual ryegrass, it was found that there is a difference when using sulfonylurea herbicides, and iodosulfuron-methyl in use alone and in combination with metsulfuron-methyl is efficient in control. The application of iodosulfuron-methyl (5.0 g a.i. ha^{-1}) and metsulfuron-methyl (2.4 g a.i. ha^{-1}) + iodosulfuron-methyl (5.0 g a.i. ha^{-1}) at 30 days after sowing resulted in higher productivity of wheat grains.
Keywords: ALS inhibitor; postemergence; *Lolium multiflorum* L.; *Triticum aestivum*

Resumo - A adoção de práticas de manejo de plantas daninhas constitui em uma das principais ferramentas que podem contribuir para o aumento da produtividade de grãos nas lavouras de trigo. O presente estudo teve como objetivo avaliar a eficiência dos herbicidas do grupo químico das sulfonilureias, isolados e em associação, em diferentes épocas da aplicação sobre a produtividade de cultivares comerciais de trigo, e no controle do azevém anual (*Lolium multiflorum* L.). O delineamento foi o de blocos casualisados, com 5 repetições. Os tratamentos foram arranjados em esquema fatorial 4 x 2 x 2, compostos pela aplicação de metsulfuron-methyl e iodosulfuron-methyl, isolados e em associação e testemunha, utilizando duas cultivares comerciais de trigo (Quartzo e BRS Tangará) em duas épocas de aplicação 21 e 30 dias após a aplicação. Foram avaliados a fitointoxicação das cultivares, o nível de controle do azevém anual e o rendimento das características agronômicas da cultura do trigo. Para o controle do azevém anual constatou-se que

[1] Received for publication on 26/09/2014 and approved on 08/10/2015.
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há diferença quando utilizado os herbicidas sulfoniluréias, sendo o iodosulfuron-methyl em uso isolado e em associação com o metsulfuron-methyl eficiente no controle. A aplicação de iodosulfuron-methyl (5,0 g i.a. ha^{-1}) e metsulfuron-methyl (2,4 g i.a. ha^{-1}) + iodosulfuron-methyl (5,0 g i.a. ha^{-1}) aos 30 dias após a semeadura resultou na maior produtividade de grãos de trigo.
Palavras-chaves: Inibidor da ALS; pós-emergência; *Lolium multiflorum* L.; *Triticum aestivum*

Introduction

The adoption of management practices in crops constitutes one of the main tools that can contribute to increased grain yield in wheat crops. The interference imposed by weeds may cause reduction in crop growth, whose intensity is usually assessed by production decreases and/or growth of the cultivated plant, as responses to competition for available resources in the environment (CO_2, water, light and nutrients) (Agostinetto et al. 2008). The degree of weed interference varies with the weed species in the area, population density, duration of the competition and environmental conditions.

In general, wheat is more sensitive to weed interference in the early stages of crop development. The critical period of competition can be extended to 50 days after plants emergence (Blanco et al., 1973). However, depending on growing conditions, this period of control must be carried out between 12 and 24 68 days after crop emergence (Agostinetto et al., 2008).

Weed control in wheat crops is based on weeds desiccation in pre-seeding by means of the use of non-selective herbicides and postemergence application of selective herbicides in the crop. In postemergence, herbicides belonging to the sulfonylureas chemical group are usually used, which inhibit the acetolactate synthase (ALS) enzyme action. Metsulfuron-methyl herbicide in postemergence is used to control various eudicotyledonous weeds, as well as iodosulfuron-methyl herbicide is used to control monocotyledonous ones, such as black oat (*Avena strigosa* L.), annual ryegrass (*Lolium multiflorum* L.) and some eudicotyledonous ones. However, ALS inhibitory herbicides can cause phytotoxicity symptoms in plant growth meristems, causing yellowing in tissues of plants with severe chlorosis; can progress to the leaves necrosis and in other cases death of some parts of the plant tissue and/or the whole plant.

Another important point to note is the mode of action of these herbicides, which, after absorption by the leaves, are rapidly translocated to active growth areas (apical meristems), promoting growth inhibition of susceptible plants, which end up dying because of the inability to produce amino acids considered essential: valine, leucine and isoleucine. Inhibition of the ALS enzyme in susceptible plants stops the production of proteins, interfering with cell division and leading to plant death (Vidal, 1997).

Because of the importance of wheat production as human food and the Brazilian population, it is essential to achieve better wheat grain yield. In this context, weed management becomes one of the fundamental factors of research, due to reduced productivity that weeds can cause and/or increase in crop production costs.

The objective of this research was to evaluate the efficiency of the chemical group of the sulfonylurea herbicides, alone and in combination, at different times of application, on the productivity of wheat cultivars, and control of annual ryegrass (*Lolium multiflorum* L.).

Material and Methods

The experiment was conducted at field level in the Brazilian municipality of Guarapuava, PR, in the geographical coordinates of: $25^{0}23'36''$ of south latitude, 51°27'19" of west longitude and 1,120 meters of altitude. The Köppen-Geiger climate classification in the region is *Cfb*-type subtropical (Peel et. al., 2007), with well distributed rainfall during the year and mild summers. The average annual temperatures range around 17 °C and rainfall reaches about 1,200 mm per year. The rainfall intensity and distribution and average temperatures for periods of ten days during the implementation period of the experiment (Figure 1) were obtained from the meteorological station of the Agronomic Institute of Paraná at approximately 300 meters from the experiment.

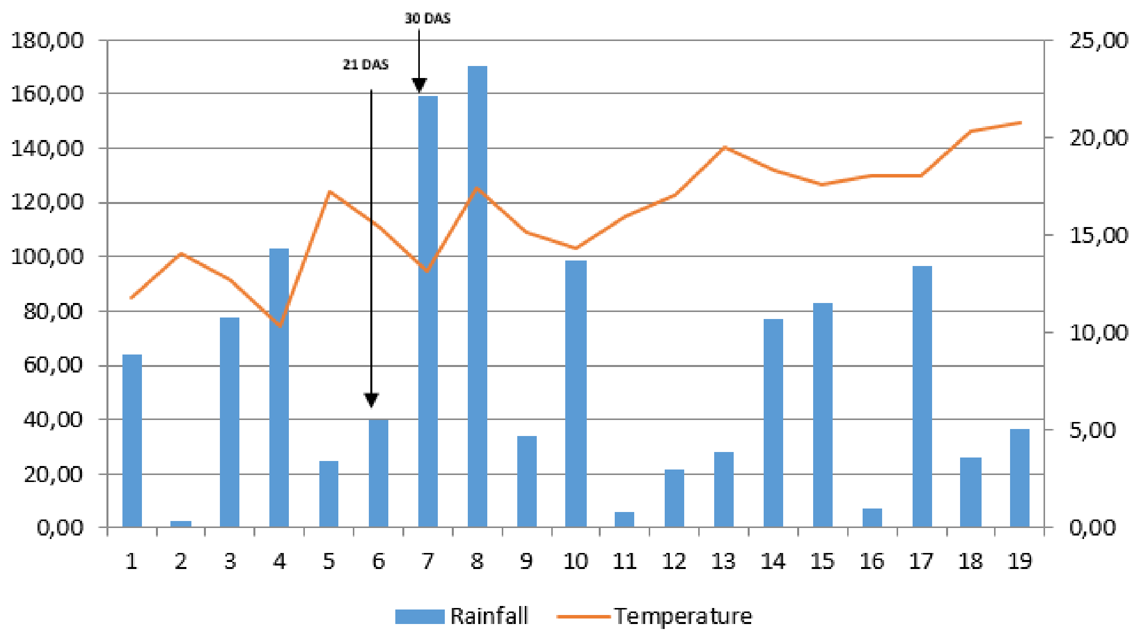

Figure 1. Average data of rainfall and average temperature, for ten days, in Guarapuava, PR, in the period from 06/01/11 to 12/10/11.

The soil of the experimental area was classified as typical distroferric bruno latosol, very clayey textured, whose chemical analysis results of the 0-20 cm deep layer presented: pH ($CaCl_2$) 5.0; 42.9 % of M.O; K: 0.18 $cmol_c$ dm^{-3}; Ca: 3.9 $cmol_c$ dm^{-3}; Mg: 2.3 $cmol_c$ dm^{-3}; Al: 0.0 $cmol_c$ dm^{-3}; H+Al: 5.1 $cmol_c$ dm^{-3}; S: 3.3 $cmol_c$ dm^{-3}e T: 11.51 $cmol_c$ dm^{-3}; V: 55.2.

The experimental design was in a randomized complete block with five repetitions. The treatments were arranged in a 4 x 2 x 2 factorial. The first factor consisted in the applied herbicides: metsulfuron-methyl – 2.4 g a.i. ha^{-1}; iodosulfuron-methyl – 5.0 g a.i. ha^{-1} and metsulfuron-methyl – 2.4 g a.i. ha^{-1} + iodosulfuron-methyl – 5.0 g a.i. 128 ha^{-1}.

Sowing of wheat cultivars Quartzo and BRS Tangará was carried out on 07/06/2011 with a SEMINA® brand/model plots seeder, according to the wheat sowing technical recommendations for Southern Brazil [Comissão Brasileira de Pesquisa de Trigo (Brazilian Commission of Wheat Research), 2013], using 180 kg ha^{-1} of seeds and a 20-cm spacing among rows to obtain the final population of 350 plants of wheat m^{-2}. The amount of fertilizers used in seeding was 250 kg ha^{-1} at the ratio of 20 kg of nitrogen, 75 kg of P_2O_5 and 50 kg of K_2O at planting furrows. To meet the crop nitrogen needs, topdressing was carried out at the ratio of 90 kg ha^{-1} N as urea (45% nitrogen).

In order to obtain a density of annual ryegrass plants with competitiveness with the wheat crop, they were sown in the experimental plots simulating a wheat area infested with annual ryegrass, in the amount of 36 kg ha^{-1} of annual ryegrass seeds (germination 80%), generating a population of annual ryegrass plants of 1,872 plants m^{-2} seeded on 07/05/2011 with the SEMINA® brand/model plots seeder. The plots had a floor area of 11.7 m^2 (5.85 x 2.0 m).

The applications of herbicides were divided into two different periods in relation to the growth stage of the wheat crop. The first application was performed 21 days after sowing (21 DAS – 07/26/2011), represented by phenological stage 2.1 (tillering – with the main tiller plus one tiller), according to the cereal development scale proposed by Zadoks et. al (1974). The second application was performed 30 days after sowing (30 DAS – 08/05/2011), represented by phenological stage 2.4 (tillering), i.e., plants with the main tiller plus four tillers. To determine the total emergence of wheat plants, the emerged seedling considered was the one which had emerged shoot more than 1 cm high.

In the stage where the annual ryegrass plants were at the time of herbicides application for the control level assessments, these had three to four leaves at the first time of herbicide application (21 DAS), and in the second time of herbicide application (30 DAS), the annual ryegrass plants had six to seven leaves.

In the applications done, a knapsack sprayer equipment pressurized at CO_2 was used, equipped with a 11002 fan-type with three nozzles, with a spray mix volume equivalent to 175 L ha^{-1} and constant pressure of 40 lb. The applications were performed in the afternoon, with temperatures averaging 20 °C, 55% relative humidity and wind speed of less than 10 km h^{-1}.

Harvest was manually done from the three central rows of all the experimental plots and the samples were processed at FAPA [Cooperativa Agrária (Agricultural Cooperative)], using as thresher the WINTERSTEIGER® mark/model plots harvester.

For the evaluation of phytointoxication symptoms caused to wheat plants by the use of the herbicides, the parameter used was by means of visual symptoms of phytotoxicity (Escala E.W.R.C., adapted by Azzi and Fernandez, 1968). Grades were assigned to visual symptoms measured 1-9, where grade 1 is no damage and grade 9 is total damage – plant death. Periods corresponding to the treatments evaluations were started three days after each application (DAA) and continued in the range of 7, 10, 14 and 17 DAA.

Assessments of annual ryegrass control level were performed at 3, 10, 17, 24 and 31 days after herbicide application. A visual scale was adopted in percentage, with 0% meaning that there was no control and 100% meaning that there was total control of the annual ryegrass plants. Visual assessments based on control level are adopted based on the weeds percentage under the effect of the applied herbicide, and this symptom is similar to the senescence process, with reference to the control plot (without herbicide application).

From the wheat plant samples collected in the three central rows of each plot, which were then threshed in a plots harvester, the following agronomic characteristics were evaluated: hectoliter weight, thousand seed weight (TSW) and grain yield. For the data obtained in the phytointoxication scale evaluations of the herbicides assessed, these were not statistically analyzed. However, the other data obtained were submitted to analysis of variance, control level and agronomic characteristics, the averages were compared by the Scott-Knott test at 5% probability, and the statistical software used was SISVAR® (Ferreira, 2002).

Results and Discussion

Rainfall occurring during the experiment exceeded 1100 mm and average temperatures were close to 17 °C in the 2011 agricultural season (Figure 1). These values are considered sufficient to obtain satisfactory wheat grain yields and thus it can be said that climate conditions during the experiment were considered normal for good development of crops.

The metsulfuron-methyl herbicide did not cause phytotoxicity symptoms in wheat cultivars, regardless of the herbicide evaluation and application times. However, the treatment with herbicide iodosulfuron-methyl and the mix metsulfuron-methyl + iodosulfuron have caused mild poisoning for cultivar Quartzo in the assessments at 3 and 7 DAA, with resolution of symptoms after these evaluations.

For the second herbicide application time (30 DAS) in cultivar Quartzo, the treatment with herbicide iodosulfuron-methyl, there was a scale 3 of phytointoxication in the assessments at 7 and 10 DAA. At 14 DAA, small chlorosis was observed in wheat plants leaves, and scale 2 was assigned. Phytointoxication symptoms were not observed in the assessments performed at 17 DAA. It is important to emphasize that in this application time (30 DAS) there was no phytotoxicity at 3 DAA, a fact that can be attributed to wheat plants being in a more advanced stage of development, which contributed to the phytointoxication symptoms being seen from 7 DAA. Phytointoxication visual scales obtained in the evaluations of the metsulfuron-methyl + iodosulfuron-methyl treatment were similar to the iodosulfuron-methyl herbicide single treatment in evaluations at 3, 7, 10, 14 and 17 DAA.

For cultivar BRS Tangará the treatments with herbicides iodosulfuron-methyl and metsulfuron-methyl + iodosulfuron-methyl, for the assessments performed on the application time at 21 DAS, averages 3 were observed for the phytotoxicity visual symptoms in both assessments performed at 3 and 7 DAA. In the assessments performed at 10 DAA in the treatments with herbicides iodosulfuron-methyl and metsulfuron-methyl + iodosulfuron-methyl, the wheat plants leaves exhibited chlorosis, but at a lower intensity, and scale 2 was assigned. From the assessments at 14 DAA, phytointoxication symptoms were not observed in the treatments with herbicides iodosulfuron-methyl and metsulfuron-methyl + iodosulfuron-methyl.

For phytointoxication assessments in cultivar BRS Tangará held in the second season of application (30 DAS), in the assessments performed at 7 and 10 DAA in the treatment with herbicides iodosulfuron-methyl and metsulfuron-methyl + iodosulfuron-methyl, the means obtained were scale 3. At 14 and 17 DAA for the treatments with herbicides iodosulfuron-methyl and metsulfuron-methyl + iodosulfuron-methyl, phytotoxicity symptoms were not observed on the wheat plants leaves. Thus, in the treatments in which metsulfuron-methyl herbicide was used, there was no chlorosis in plant tissues relative to other treatments where iodosulfuron-methyl and metsulfuron-methyl + iodosulfuron-methyl herbicides were used.

It was found that there was no response from metsulfuron-methyl herbicide for the control of annual ryegrass seedlings for the two application periods (Table 1), since the metsulfuron-methyl herbicide does not have a technical recommendation for the control of annual ryegrass. Annual ryegrass seedlings control assessments in relation to herbicide treatments began at 3 DAA, and, by means of evaluations carried out, it was possible to observe the beginning of control during the evaluations performed from 10 DAA.

When performing the first application time (21 DAS) on cultivar Quartzo, evaluations in the treatment with herbicide iodosulfuron-methyl, single treatment, demonstrated that the level of annual ryegrass control began at 10 DAA with 10% efficiency over the annual ryegrass seedlings. The control efficiency reached 72% at 17 DAA and 90% at 24 DAA, and index considered to be satisfactory for the level of infestation by the annual ryegrass seedlings. However, it was observed in the assessments performed at 31 DAA that there was total control of these annual ryegrass seedlings (Table 1).

The treatment with herbicide metsulfuron-methyl + iodosulfuron-methyl presented efficiency data in controlling annual ryegrass seedlings that were very close relative to iodosulfuron-methyl applied alone. Thus, at 10 DAA the efficiency in the control reached 15% of the annual ryegrass seedlings. At 17 DAA the efficiency in controlling achieved 74% and at 24 DAA it achieved 90%, an index considered to be satisfactory for annual ryegrass seedlings control over the level of infestation that was established. In evaluations carried out at 31 DAA, full control of annual ryegrass seedlings was observed.

Table 1. Average values in percent (%) for the control of annual ryegrass in two seasons of sulfonylurea herbicide applications. Guarapuava (PR), 2011.

Assessment DAA	Application times – cv. Quartzo							
	21 DAS – (Stage 2.2)				30 DAS – (Stage 2.4)			
	Control	MET	IOD	MET + IOD	Control	MET	IOD	MET + IOD
10	0 aA	0 aA	10 bB	15 bB	0 aA	0 aA	40 bA	35 bA
17	0 aA	0 aA	72 aA	74 aA	0 aA	0 aA	75 aA	77 aA
24	0 aA	0 aA	90 aA	90 aA	0 aA	0 aA	95 aA	100 aA
31	0 aA	0 aA	100 aA	100 aA	0 aA	0 aA	100 aA	100 aA
Assessment DAA	Application times – cv. BRS TANGARÁ							
	21 DAS – (Stage 2.2)				30 DAS – (Stage 2.4)			
	Control	MET	IOD	MET + IOD	Control	MET	IOD	MET + IOD
10	0 aA	0 aA	10 bB	15 bB	0 aA	0 aA	56 bA	58 bA
17	0 aA	0 aA	73 aA	80 aA	0 aA	0 aA	80 aA	80 aA
24	0 aA	0 aA	100 aA	100 aA	0 aA	0 aA	100 aA	100 aA
31	0 aA	0 aA	100 aA	100 aA	0 aA	0 aA	100 aA	100 aA

MET = Metsulfuron; IOD = Iodosulfuron. Means followed by the same lowercase letters in columns and uppercase letters in the row comparing each treatment and application time are not statistically different from each other by the Scott-Knott test at the level of probability ($p \leq 0.05$).

However, when compared to the second time of application (30 DAS) on cultivar Quartzo, the results obtained showed a higher level of control of annual ryegrass seedlings, especially during evaluation at 10 DAA, with values of 40 and 35% of control for treatment with herbicides iodosulfuron-methyl and metsulfuron-methyl + iodosulfuron-methyl, respectively. For the evaluations of treatment with herbicide iodosulfuron-methyl at 17 DAA, the control efficiency of annual ryegrass seedlings was 75% and at 24 DAA control efficiency was 95%, being considered a satisfactory control rate. Data from the treatment with herbicide metsulfuron-methyl + iodosulfuron-methyl in percentage terms are pretty much similar to the data obtained from the treatment with herbicide iodosulfuron-methyl and do not express great efficiency difference in controlling annual ryegrass seedlings from evaluations at 17 DAA (Table 1).

This fact allows us to infer that there was an application time effect in terms of annual ryegrass seedlings control, depending on the time of application, regardless of the herbicide treatment used (Table 1).

Evaluations of herbicide treatments for cultivar BRS Tangará at the application time at 21 DAS allowed the observation that at 10 DAA the average efficiency data in the control were 10% and 15% for the treatments with herbicides iodosulfuron-methyl isolated and metsulfuron-methyl + iodosulfuron-methyl, respectively. In the control of annual ryegrass seedlings in the evaluations carried out at 17, 24 and 31 DAA in relation to treatments with herbicides iodosulfuron-methyl and metsulfuron-methyl + iodosulfuron-methyl, the 73% and 80% control percentages were obtained for evaluations at 17 DAA, respectively. From the evaluations at 24 DAA there was a satisfactory rate of annual ryegrass seedlings control of iodosulfuron-methyl and metsulfuron-methyl + iodosulfuron-methyl.

The same fact was observed when assessing the second time of application (30 DAS) on cultivar BRS Tangará, where the values obtained at 10 DAA are numerically higher than those obtained in cultivar Quartzo, values corresponding to 56 and 58% efficiency in the control of annual ryegrass seedlings in the treatments with herbicides iodosulfuron-methyl and metsulfuron-methyl + iodosulfuron-methyl, respectively.

With evaluations carried out for the control of annual ryegrass seedlings present in wheat crops in two different periods of application it was evident that by the use of herbicide metsulfuron-methyl there was no effect on the annual ryegrass seedlings, an effect expected since the herbicide does not have technical recommendation for the control of annual ryegrass. With the use of herbicides iodosulfuron-methyl and metsulfuron-methyl + iodosulfuron-methyl, there was a satisfactory control of annual ryegrass seedlings on cultivar Quartzo only from assessments carried out at 24 DAA for both application times.

However, for cultivar BRS Tangará with the use of iodosulfuron-methyl herbicide for the first application time (21 DAS), the total control of annual ryegrass seedlings was obtained from 24 DAA. In association of herbicides metsulfuron-methyl and iodosulfuron-methyl, an 80% control of annual ryegrass plants at 17 DAA was already noticed, and compared with the same time assessed for the same cultivar, the percentages of control with the use of the iodosulfuron-methyl herbicide were still unsatisfactory. For the second time of application (30 DAS), levels of control of annual ryegrass seedlings from 17 DAA were found satisfactory, with efficient control of 80% when using herbicides iodosulfuron-methyl and metsulfuron-methyl + iodosulfuron-methyl.

In a study conducted by Trezzi et al. (2007), they have evaluated annual ryegrass control in wheat crops using the herbicide clodinafop-propargyl in combination with metsulfuron-methyl and 2,4-D and in isolation; they found that there was an antagonism in the use of the association of molecules clodinafop-propargyl with metsulfuron-methyl. Even in the lowest dosage of metsulfuron-methyl it was able to harm the action of the graminicide, and it was necessary to increase the herbicide dosage, so that a satisfactory level of control would be achieved, thus overcoming the antagonism between molecules.

However, Trezzi et al. (2007) have inferred that the low interference of annual ryegrass plants with wheat was evidenced by the competitive ability of wheat plants compared to annual ryegrass, providing no significant reduction in yield grains. But the authors point out that the increased density of annual ryegrass plants from 29 to 118 plants m^2 has reduced wheat yield between 7 and 50%, according to Appleby et al. (1976). In this study, the density of annual ryegrass plants was considered high, and this methodology of study has aimed to enable comparison of their effects on the evaluated wheat cultivars and sulfonylurea herbicides.

In the individual analysis of variance for hectoliter weight (HW), thousand seed weight (TSW) and grain yield (GY), significant differences were observed ($p \leq 0.01$ and $p \leq 0.05$) among the sources of variation for the evaluated characteristics.

There were significant effects for the treatment versus application time interaction for hectoliter weight and grain yield; this fact indicates that there were differences in pH values between treatments with herbicides evaluated, and these also influenced grain yield when evaluating the two application times (21 DAS and 30 DAS) (Table 2).

When analyzing the treatment versus cultivar interaction, this one showed a significant effect for hectoliter weight, demonstrating that the treatments tested showed different levels for HW values when evaluated in two wheat cultivars. The application time versus cultivar interaction showed significant differences for the character hectoliter weight, indicating that depending on the herbicide application timing, there was an influence on the two wheat cultivars in relation to the values obtained for the hectoliter weight (Table 2).

For the application time at 21 DAS, when assessing cultivar Quartzo there was a significant difference for the hectoliter weight character only in the treatment with herbicide metsulfuron-methyl + iodosulfuron-methyl, and the best results obtained for hectoliter weight on this treatment were observed (Table 2).

In relation to cultivar BRS Tangará for the application time at 21 DAS the best hectoliter weight results in treatments with herbicide iodosulfuron-methyl and metsulfuron-methyl + iodosulfuron-methyl were obtained, when compared to the metsulfuron-methyl treatment and control without application.

Table 2. Average values of hectoliter weight expressed in kg hL^{-1} of two wheat cultivars in two application periods. Guarapuava (PR), 2011.

Treatments	Hectoliter weight (HW)				Average
	21 DAS		30 DAS		
	Quartzo	BRS Tangará	Quartzo	BRS Tangará	
Control	73.82 bA	75.00 bA	75.45 aA	75.00 cA	75.82 b
MET	74.45 bA	74.68 bA	75.98 aA	76.34 bA	75.92 b
IOD	76.47 bA	76.71 aB	76.61 aA	79.56 aA	76.42 a
MET + IOD	77.01 aA	77.72 aB	76.84 aA	79.44 aA	77.25 a
Average	75.27 B	76.03 B	76.22 A	77.59 A	
Average	75.65 B		76.90 A		CV 1.95%

MET = Metsulfuron; IOD = Iodosulfuron. Means followed by the same lowercase letters in columns and uppercase letters in the row comparing each treatment and application time are not statistically different from each other by the Scott-Knott test at the level of probability ($p \leq 0.05$).

For the application time at 30 DAS, there was a significant difference for the different treatments with sulfonylurea herbicides for cultivar BRS Tangará, and the best results for hectoliter weight were obtained from the treatments with herbicides iodosulfuron-methyl and metsulfuron-methyl + iodosulfuron-methyl, a treatment in combination, and these ones statistically differed from the treatment with herbicide metsulfuron-methyl, single treatment, which obtained the value of 76.34. In this case, all treatments with sulfonylurea herbicides metsulfuron-methyl and iodosulfuron-methyl, single treatments, and metsulfuron-methyl + iodosulfuron-methyl, treatment in combination differed from the control treatment.

When comparing the different application times (21 DAS and 30 DAS), a significant difference was observed in cultivar BRS Tangará for treatments with iodosulfuron-methyl and metsulfuron-methyl + iodosulfuron-methyl, and the best results obtained were in the second season of application (30 DAS); the same did not occur when evaluating cultivar Quartzo, which showed no significant differences among treatments depending on the application time (Table 2).

The “treatment versus application time” interaction was significant for the character thousand seed weight (Table 3). It was observed that the treatments with herbicides iodosulfuron-methyl and metsulfuron-methyl + iodosulfuron-methyl proved to be better at 30 DAS in relation to 21 DAS. Treatment with herbicide metsulfuron-methyl showed no significant difference for TSW among different application times.

When comparing the average values, the greatest PMS values were observed at the time of application at 30 DAS compared to 21 DAS, demonstrating that for the character thousand seed weight there was an increase in the mass accumulation in the grains. The treatment metsulfuron-methyl + iodosulfuron-methyl obtained the highest average of PMS: 35.74g, statistically different from the other treatments with sulfonylurea herbicides and the control. This way it is possible to show that the choice of sulfonylurea herbicide targeting the management of weeds present in the area, in this more specific case, annual ryegrass, has an effect on wheat grain filling, regardless of the cultivar used.

For the variable grain yield, the interaction “treatment versus application time” was significant (Table 3) when comparing the different herbicides and application times. In the first application time (21 DAS) there were significant differences among the different treatments with sulfonylurea herbicides, and the treatment with metsulfuron-methyl + iodosulfuron-methyl had the highest grain yield values: 4,834 kg per hectare, statistically different from the other treatments with herbicides.

Table 3. Average values of thousand seed weight (TSW) and grain yield (GY) under two seasons of application of sulfonylurea herbicides. Guarapuava, PR.

Treatments	PMS (g)		Average	GY (kg ha^{-1})		Average
	21 DAS	30 DAS		21 DAS	30 DAS	
Control	31.73 aA	33.03 Ca	32.86 c	3,616 cA	3,762 cA	3,739 c
MET	33.27 aA	34.89 Ba	34.08 b	3,909 cA	3,935 bA	3,922 b
IOD	32.99 aB	35.13 bA	34.06 b	4,408 bB	4,886 aA	4,697 a
MET + IOD	34.33 aB	37.16 Aa	35.74 a	4,834 aA	4,911 aA	4,873 a
Average	33.08 B	35.17 A	CV – 6.92%	4,192 B	4,374 A	CV – 5.52%

MET = Metsulfuron; IOD = Iodosulfuron. Means followed by the same lowercase letters in columns and uppercase letters in the row comparing each treatment and application time are not statistically different from each other by the Scott-Knott test at the level of probability ($p \leq 0.05$).

However, among the evaluated herbicide treatments in the second application time (30 DAS), there was a significant difference, where in the isolated use of herbicide iodosulfuron-methyl and in association with metsulfuron-methyl the best yields of wheat were observed, when comparing to the herbicide metsulfuron-methyl, single treatment and the control (Table 3).

Having as a comparative the treatment with herbicide iodosulfuron-methyl isolated, it became evident that there was an increase in grain yield, depending on the application time, and the second time of application (30 DAS) was statistically different from the first application time at 21 DAS.

Metsulfuron-methyl + iodosulfuron-methyl showed no significant differences in grain yield for application times 21 DAS and 30 DAS. On the average, in the “treatment versus application time” interaction, significant difference was found for wheat grain yield in relation to the application time, where the best results were obtained at 30 DAS.

According to Albrecht et al. (2010), they have pointed out the existence of deleterious effects on wheat crops with the use of metsulfuron-methyl herbicide for applications carried out in the reproductive stage (10.4). In a polynomial regression analysis, the authors observed an effect of metsulfuron-methyl doses on yield, which showed a linear decrease due to an increase in herbicide doses. Therefore, for the increase of each g ha^{-1} of metsulfuron-methyl, there was a decrease of 30.69 kg ha^{-1} in the wheat seeds yield. Albrecht et al. (2010) point out that applications done in the growing season with metsulfuron-methyl herbicide have not obtained significant inference on the grain yield.

For Cargnin et al. (2006), in a study using selective herbicides in oat production showed significant results in relation to genotype versus herbicide interaction, demonstrating that there was superiority in oat grains yield when using herbicides, compared to the control. The authors found different behaviors of the genotypes used in relation to the herbicide used. However, there was a superior performance for hectoliter weight and thousand seed weight related to herbicide rates, compared to the control treatment.

For wheat under the effect of the herbicides, in terms of the yield, Cargnin et al. (2006) have found that metsulfuron-methyl herbicide showed better response and less variation in grain yield, hectoliter weight and thousand seed weight. The authors emphasize that the use of herbicides in weed control on oat genotypes made it possible to see the reduction of losses in grain yield caused by the competition from weeds.

Conclusions

For the control of annual ryegrass, it was found that there is a difference when using sulfonylurea herbicides, and iodosulfuron-methyl in use alone and in combination with metsulfuron-methyl was an efficient option.

The application of iodosulfuron-methyl (5.0 g a.i. ha^{-1}) and metsulfuron-methyl (2.4 g a.i. ha^{-1}) + iodosulfuron-methyl (5.0 g a.i. ha^{-1}) at 30 days after sowing resulted in higher yield of wheat grains.

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