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Cloransulam-methyl efficiency in postemergence control of *Conyza bonariensis* in RR™ soybeans crops[1]

Eficiência do cloransulam-metílico no controle em pós-emergência de ***Conyza bonariensis*** *na cultura da soja RR®*

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Abstract - With the introduction of transgenic soybean resistant to glyphosate, which was widespread in southern Brazil, the number of applications and the selection of biotypes of horseweed (*Conyza bonariensis*) resistant to herbicide have stepped up. Thus, new chemical alternatives are essential for the efficient control of horseweed. Thus, the aim of this study was to evaluate the effectiveness of cloransulam-methyl (Pacto™), applied in postemergence, in controlling *C. bonariensis* and SYN 1059 RR Vtop™ soybean yield. The experiment was conducted in the Brazilian municipality of Assis Chateaubriand, PR, in an experimental design of randomized blocks with four replications. The treatments consisted in doses of cloransulam-methyl (25, 30, 35 and 40 g a.i. ha^{-1}), chlorimuron-ethyl (20 g a.i. ha^{-1}) and weeded and unweeded controls. The horseweed plants were between 5 to 10 cm high and had an average density of 35 plants per m^2. Cloransulam-methyl, at doses of 25 and 30 g ha^{-1}, did not manage horseweed efficiently (< 80%) from 28 DAA (days after application), being inferior to chlorimuron-ethyl. However, cloransulam-methyl at 40 to 35 g ha^{-1} showed horseweed control (87.0% and 90.7%), which did not differ significantly from chlorimuron-ethyl at 42 DAA (85.7%) and it did not cause symptoms of injuries and soybean productivity reduction either. Cloransulam-methyl, despite not having been effective in controlling *C. bonariensis* at 30 g ha^{-1}, showed soybean yield similar to the weeded control, and superior to chlorimuron-ethyl. The weed interference caused by the horseweed infestation reduced soybean yield in 47.5%.
Keywords: *Glycine max*; horseweed; ALS inhibitor; productivity

Resumo - Com a introdução da soja transgênica resistente ao glyphosate, a qual foi amplamente difundida na região sul do Brasil, intensificou-se o número de aplicações e a seleção de biótipos de buva (*Conyza bonarienses*) resistente ao herbicida. Desta maneira, são fundamentais novas alternativas químicas para o controle eficiente de buva. Diante disso, o objetivo deste trabalho foi avaliar a eficácia do cloransulam-metílico (Pacto®), aplicado em pós-emergência, no controle de

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C. bonariensis e produtividade da soja SYN 1059 RR Vtop®. O experimento foi conduzido no município de Assis Chateaubriand-PR, em delineamento experimental de blocos ao acaso, com quatro repetições. Os tratamentos constituíram das doses de cloransulam-metílico (25, 30, 35 e 40 g i.a. ha^{-1}), clorimuron-etílico (20 g i.a. ha^{-1}) e testemunhas capinada e sem capina. As plantas de buva encontravam-se entre 5 a 10 cm de altura e densidade média de 35 plantas por m^2. Cloransulam-metílico, nas doses de 25 e 30 g ha^{-1}, não controlou de forma eficiente a buva (<80%) a partir dos 28 DAA (dias após aplicação), sendo inferior ao clorimuron-etílico. Entretanto, cloransulam-metílico a 35 e 40 g ha^{-1} apresentou controle de buva (87,0% e 90,7%) não diferindo significativamente do clorimuron-etílico aos 42 DAA (85,7%), assim como não ocasionando sintomas de injúrias e redução de produtividade à cultura da soja. Cloransulam-metílico apesar de não ter sido eficiente no controle de *C. bonariensis* a 30 g ha^{-1}, apresentou produtividade da soja semelhante à testemunha capinada, e superior ao clorimuron-etílico. A matointerferência ocasionada pela infestação de buva reduziu a produtividade da soja em 47,5%.
Palavras-chaves: *Glycine max*; buva; inibidor de ALS; produtividade

Introduction

Soybean (*Glycine max*) is one of the crops with greater acreage in Brazil and, consequently, greater economic importance for the country, as it is responsible for exporting grains and derivatives. In the 2012/13 harvest season there was an increase of 10.8% in Brazilian acreage relative to 2011/12 from 25.0 million hectares to 27.7 million, with a production of 81.5 million tonnes and average productivity of 2,938 kg ha^{-1} (CONAB, 2014).

Competition from weeds is one of the factors that most affect crop yields of economic interest to man, causing damage not only in agricultural production. The knowledge of the area infesting weeds species is important for farmers, because it facilitates the use of a more suitable handling and, particularly, it allows constant monitoring of the weed flora change, both in terms of predominant species and of biotypes within each species (Christoffoleti, 1998).

Horseweed (*Conyza bonariensis*) is a species originated in South America and belongs to the Asteraceae family. This weed has been reported in seventy countries, infesting more than forty cultures (Holm et al., 1997); it is considered to be too prolific, with capacity to produce 230,000 seeds, which are small and easily dispersed by wind (Lazaroto et al., 2008). The germination of horseweed seeds is favored by light and has greater germination potential at temperatures around 20 °C. However, when positioned at depth equal to or greater than one centimeter, the emergence is drastically reduced and may also be influenced by soil texture (Vidal et al., 2007).

In addition to the high ability to produce seeds and adaptability, horseweed negative capability caused in crop productivity stands out. According to Patel et al. (2010), the higher the horseweed density and the period between its appearance and soybean seeding, the highest the income losses caused to RR® soybeans. Gazziero et al. (2010) have mentioned that densities of 12.2 and 55.6 horseweed plants per m^2 living with the soybean crop since the emergence have caused reduced productivity around 700 and 1500 kg ha^{-1}, respectively. Trezzi et al. (2013), studying the simulation of interference of 13.3 horseweed plants per m^2 transplanted seven days before soybean sowing (CD 225 RR™, BRS 232™, CD 226 RR™, NK 7054 RR™, BMX Apollo RR™, BRS 245 RR™ and BRS 255 RR™), have found an average 25% loss of grain yield. Similarly, in cotton crops in the United States, Steckel et al. (2009) have reported that 20 horseweed plants per m^2 reduced crop yield by 46%. For other cultures, Holm et al. (1997) have reported that the coexistence of horseweed infestation with sugar beet reduced its productivity by 64% and

23% in the development of the vine crop branches.

Therefore, with the introduction of transgenic soybean technology resistant to glyphosate, the number of product applications containing only this active ingredient has intensified, causing biotypes of horseweed (*C. bonariensis*) resistant to glyphosate to be selected (Vargas et al., 2007). In countries where such technology was pioneered, the incidence of other glyphosate-resistant weeds has also simultaneously occurred (Powles et al., 1998; Powles, 2003). In this sense, research aimed at studying new chemical alternatives for the efficient control of horseweed is critical and necessary to circumvent this problem in RR™ soybeans crops.

According to Vargas and Gazzieiro (2009), to control horseweed in soybean postemergence, herbicides chlorimuron or cloransulam may be used. However, these do not have high levels of control under these conditions and often only provide a suppressive effect on horseweed, which recovers and completes its cycle, producing seeds. Fornarolli et al. (2010) and Bressanin et al. (2014) have found that the combination of glyphosate + chlorimuron-ethyl provided horseweed control of 85% and 95%, respectively, when applied in plants with 4 to 6 leaves.

Thus, the study aimed to evaluate the effectiveness of the herbicide cloransulam-methyl applied in postemergence in control of *Conyza bonariensis*, as well as the RR™ soybean yield.

Material and Methods

The experiment was conducted at the experimental station Terra Paraná Pesquisa e Treinamento Agrícola, located at Gleba Silveira – lots 180, 181 and 182, in the municipality of Assis Chateaubriand, PR, whose geographic coordinates were latitude 24°17’39,78” south, longitude 53°35’16.56” west, and average altitude 315 m. The climate in the region is classified by Köppen as Cfa, namely mesothermal humid subtropical, with hot summers, infrequent frosts and a concentrated rainfall trend in the summer months with no clear dry season (Caviglione, 2000).

The soil of the experimental area was classified as Oxisol Eutrudox (EMBRAPA, 2013) and presented pH, in $CaCl_2$, of 4.20; 7.20 $cmol_c$ of H^++$Al^{+3}$$dm^{-3}$ of soil; 2.18 $cmol_c$ dm^{-3} of Ca^{+2}, 1.21 $cmol_c$ dm^{-3} of Mg^{+2}; 0.34 $cmol_c$ dm^{-3} of K^+; 29.57 mg dm^{-3} of P; 14.53 g dm^{-3} of M.O.; 15.0% of sand; 12.5% of silt and 72.5% of clay.

The test was carried out from 11/04/2013 to 02/02/2014. The experimental design was in randomized blocks, with seven treatments and four replications. The experimental unit consisted in plots with 5.0 m wide by 5.0 m long dimensions (25.0 m^2). The treatments were a combination of cloransulam-methyl herbicide (Pacto™) at doses of 25, 30, 35 and 40 g a.i. ha^{-1}, chlorimuron-ethyl (Classic™) at the dose of 20 g a.i. ha^{-1}, and weeded and unweeded control. Herbicides cloransulam-methyl and chlorimuron-ethyl were used associated to adjuvants Agral™ (nonylphenoxypoly (ethyleneoxy) ethanol) and Join Oil™ (mineral oil), respectively, at doses of 0.2% and 0.5% of volume/volume.

Soybean crop sowing, cultivar Syngenta V-TOP 1059 RR™, was performed on October 6, 2013, using as base fertilization 206 kg ha^{-1} of formulated 02-20-18 (NPK), sowing density of 18 seeds per meter and rows spacing of 43 cm. Maintenance applications consisted of an application of insecticide teflubenzuron (Nomolt 150™ 50 mL p.c. ha^{-1}) for caterpillar control on 11/18/2013, an application of the fungicide pyraclostrobin + epoxiconazole (Ópera™ 600 mL p.c. ha^{-1}) on 12/19/2013, and an application of insecticide imidacloprid + beta-cyfluthrin (Connect™ 1000 mL p.c. ha^{-1}) for the control of seed bugs and caterpillars on 01/15/2014.

The herbicide treatment application was carried out in the late afternoon on 11/04/2013 using a knapsack sprayer at constant pressure based on CO_2, equipped with a XR110.02 fantype five-nozzle spray boom, under pressure of 2.0 kgf cm^{-2}, which provided a spray mix of 200 L ha^{-1}. Weather conditions at the time of application were clear sky, moist soil, relative humidity of 63%, average air temperature of 26.5 °C and winds speed of 1.35 km h^{-1}. At the time, soybeans cultivar SYN 1059 RR Vtop™ was in stage V1/V2, as well the infestation consisting in *C. bonariensis* plants in a stage between 5 to 10 cm high, and average density of 35 plants per m^2. The other weed species and *C. bonariensis* plants that did not fit in the 5-10 cm stage were manually removed from all experimental units.

Meteorological data observed during the experiment are arranged in Figure 1, and they were directly collected into an automatic station Estação Automática Davis Vantage Pro2 Plus, Model 6163, located in the very experimental area.

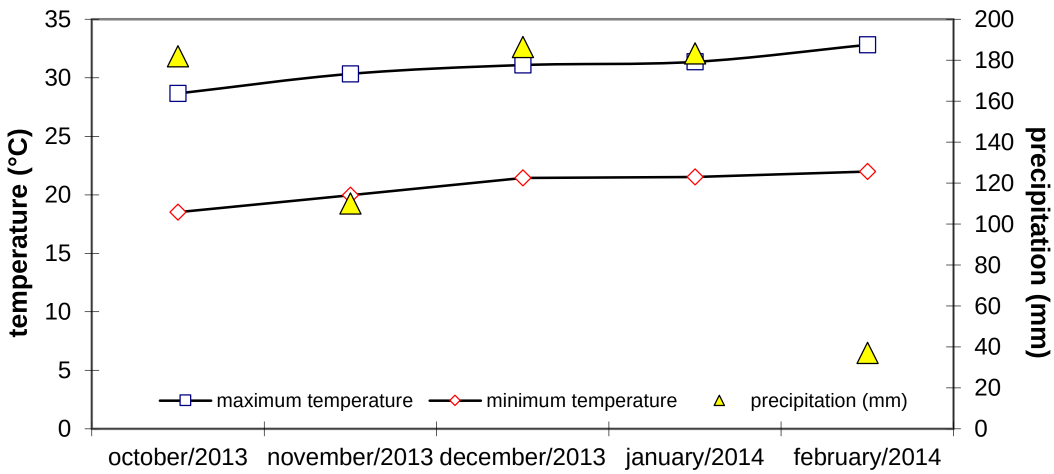

Figure 1. Climatological data for temperature (°C) and average rainfall (mm) over the period from implementation to SYN 1059 RR Vtop™ soybean crop harvest. Assis Chateaubriand, PR, 2013/2014.

The characteristics evaluated were: percentage of control at 7, 14, 21, 28, 42 days after application (DAA) and in preharvest, based on visual scale of injuries grades, where 0% meant no injury and 100 % meant plant death (SBCPD, 1995); crop phytointoxication at 7, 14 and 21 DAA by means of the EWRC (European Weed Research Council) (1967) scale, where 1 means no crop injuries and 9 means death of plants; the *C. bonariensis* plants number count per m^2 at 28 and 42 DAA; and grain yield corrected for 14% moisture, considering the six central 4 m long rows.

Control data, number of horseweed plants and soybean yield were submitted to analysis of variance by the F-test and the averages were compared by the Tukey's test at 10% probability.

Results and Discussion

Initially, at 7 days after application (DAA) there was no significant difference among the herbicide treatments efficiency, and the control levels of *C. bonariensis* (horseweed) were 55.0% to 62.5% (Table 1). At 14 DAA, the herbicide treatments had efficiency similar to or higher than 83.7%, where cloransulam-methyl at the highest dose (40 g a.i. ha^{-1}) excelled compared to the lowest doses, as well as chlorimuron-ethyl (20 g a.i. ha^{-1}). All herbicide treatments had control levels above the minimum agronomically acceptable (≥ 80.0%)

at 21 DAA, according to criteria by SBCPD [Sociedade Brasileira da Ciência das Plantas Daninhas (Brazilian Society of Weed Science)] (1995), where doses of 35 and 40 g a.i. ha^{-1} of cloransulam-methyl were higher than the doses of 25 and 30 g a.i. ha^{-1}, demonstrating that higher doses of this product significantly improved its performance in controlling *C. bonariensis*.

Table 1. *Conyza bonariensis* control percentage for herbicides applied in postemergence of the RR® soybean crop. Assis Chateaubriand, PR, 2013/2014.

Treatments	Dose g a.i. ha^{-1}	7 DAA[/1]		14 DAA		21 DAA		28 DAA		42 DAA		Preharvest	
1. Cloransulam[/2]	25	55.0	b	81.3	c	83.7	d	70.7	d	67.0	c	63.7	d
2. Cloransulam	30	60.0	b	84.5	c	85.3	cd	74.5	d	71.3	c	68.7	cd
3. Cloransulam	35	60.0	b	84.5	c	92.3	b	91.0	bc	87.0	b	82.0	bc
4. Cloransulam	40	62.5	b	89.0	b	92.7	b	94.0	b	90.7	b	82.5	bc
5. Chlorimuron[/3]	20	55.0	b	83.3	c	89.3	bc	88.3	c	85.7	b	83.3	b
6. Unweeded control		0.0	c	0.0	d	0.0	e	0.0	e	0.0	d	0.0	e
7. Weeded control		100.0	a	100.0	a	100.0	a	100.0	a	100.0	a	100.0	a
Fcal		172.98*		1467.05*		737.98*		1409.29*		590.75*		94.91*	
LSD (10%)		9.26		3.63		5.30		3.80		5.74		13.84	
CV (%)		7.94		2.34		3.29		2.47		3.85		9.70	

– /1 DAA = days after application; – Application with Agral™/2 (0.2% v/v) and Joint Oil™/3 (0.5% v/v). – Means followed by the same letter in the column do not differ by Tukey test ($p \leq 0.10$). * = significant.

From 28 DAA to the preharvest, cloransulam-methyl in the doses of 25 and 30 g a.i. ha^{-1} provided insufficient control level and below the acceptable minimum, being below chlorimuron-ethyl (20 g a.i. ha^{-1}) (Table 1). Conversely, doses of 35 and 40 g a.i. ha^{-1} kept control between 94.0% and 82.0% of horseweed infestation, and behavior similar to chlorimuron-ethyl. These results confirm the technical recommendations by Lorenzi (2014) who classifies the *C. bonariensis* species as being highly susceptible and susceptible, respectively, when submitted to the application in early postemergence of cloransulam-methyl and chlorimuron-ethyl. Bressanin et al. (2014) have also mentioned that the association of glyphosate + chlorimuron-ethyl provided an excellent level of horseweed control in plants in a stage of 4-6 leaves.

Increased cloransulam-methyl dose significantly improved performance in horseweed control, equating it to chlorimuron-ethyl and to the assessment done in the crop preharvest. Thus, the herbicides dose conditions and the phenological stage of the *C. bonariensis* weed were essential to maintain the efficiency of the herbicides studied. For Procópio et al. (2003), the high trichromatic density, cuticle thickness, lower stomatal density and presence of epicuticular wax, especially in the adaxial leaf surface, are considered leaf barriers to the penetration of herbicides in *C. bonariensis*. In this regard, Santos et al. (2014) have indicated that the explanation for the lower sensitivity of the *Conyza sumatrensis* biotypes to chlorimuron-ethyl in vegetative stages above six leaves (> 10 cm) is the absorption reduction due to factors related to the leaf external anatomy, such as the presence of trichomes.

The figures for horseweed plants density per m^2 assessed at 28 and 42 DAA are found in Table 2. Overall, in both evaluations, the herbicide treatments with doses of cloransulam-methyl and chlorimuron-ethyl did not differ, but had number of plants per m^2 significantly lower than in the unweeded control. Therefore, it is important to note that the average number of horseweed plants per m^2 in herbicide treatments was at least 2.93 times lower than the unweeded control, and for cloransulam-methyl, in all evaluated doses, it was similar to chlorimuron-ethyl (Table 2).

Table 2. Density of *Conyza bonariensis* (plants per m^2) subjected to herbicide application in postemergence of the RR^{TM} soybean crop. Assis Chateaubriand, PR, 2013/2014.

Treatments	Dose g a.i. ha^{-1}	28 DAA[/1]		42 DAA	
1. Cloransulam[/2]	25	36.5	b	36.0	b
2. Cloransulam	30	30.0	b	42.5	b
3. Cloransulam	35	25.5	b	44.3	b
4. Cloransulam	40	29.5	b	34.7	b
5. Chlorimuron[/3]	20	26.5	b	35.0	b
6. Unweeded control	–	139.7	c	130.0	c
7. Weeded control	–	0.0	a	0.0	a
Fcal	–	67.30*		38.09*	
LSD (least significant difference) (10%)	–	22.83		26.86	
CV (%)	–	26.69		28.04	

– [/1] DAA = days after application; – Application with Agral[TM/2] (0.2% v/v) and Joint Oil[TM/3] (0.5% v/v). – Means followed by the same letter in the column do not differ by Tukey test (p≤ 0.10). * = significant.

Importantly, despite the high suppression in the density of horseweed plants present in the area at 28 and 42 DAA, by means of the application of herbicides cloransulam-methyl and chlorimuron-ethyl (Table 2), other complementary control measures must be effective to prevent uncontrolled horseweed plants to be able to produce seeds by the end of the soybean crop cycle. In this sense, the integration of effective measures for cultural and chemical control, aimed at fast closing inter-rows and the smallest soybean crop phytotoxicity, such as the use of earlier and selective cultivars, is an important tool for the management of production systems with the presence of the *C. bonariensis* species.

The phytointoxication data of SYN 1059 RR Vtop^{TM} soybean cultivar after the application of herbicide treatments as well as productivity are shown in Table 3. With regard to plant intoxication, it was observed at 7 DAA that only chlorimuron-ethyl provided symptoms of visual injury to the soybeans crop, which consisted in chlorosis, characterized by strong yellowing that occurred widespread in all plots and mild corrugation of the newest leaf trefoils. However, at 14 and 21 DAA, no visual symptoms of injury in the shoot were observed. These results are consistent with those observed by Maciel et al. (2011) and Neves et al. (2011), who have also found signs of more intense visual phytotoxicity in soybean cultivars CD-214^{TM} and P98Y40^{TM}, respectively, for the association of glyphosate + chlorimuron-ethyl (540 + 10 and 960 + 20 g ha^{-1}), and practically absence of symptoms with glyphosate + cloransulam-methyl (540 + 30 and 960 + 40 g ha^{-1}).

As for grain yield, it was observed that the unweeded control was significantly lower than the other treatments, producing 47.5% less than the weeded control (Table 3). This information shows how much horseweed may adversely affect the soybean crop, confirming information reported by Gazziero et al. (2010), Patel et al. (2010) and Trezzi et al. (2013), and demonstrating that effective control measures must be taken to remedy and/or reduce the losses caused by this invasive species. Accordingly, among the herbicidal treatments, chlorimuron-ethyl scored significantly lower grain yield than cloransulam-methyl in all studied doses. This result may be related to herbicide selectivity level to cultivar SYN 1059 RR Vtop^{TM}, since only chlorimuron-ethyl provided visual symptoms of injury to crop.

The application in postemergence of *C. bonariensis* from 30 g a.i. ha^{-1} of cloransulam-methyl, has ensured RR^{TM} soybeans crop yield similar to the weeded control, and even being below chlorimuron-ethyl regarding efficient control at this dose, it stood out as one of the best treatments in terms of selectivity.

Table 3. Phytointoxication and productivity of RR™ soybean grains submitted to herbicide application in postemergence. Assis Chateaubriand, PR, 2013/2014.

Treatments	Dose g a.i. ha^{-1}	Phytointoxication (EWRC; European Weed Research Council)			Yield (kg ha^{-1})
		7 DAA/1	14 DAA	21 DAA	
1. Cloransulam/2	25	1	1	1	2676.5 b
2. Cloransulam	30	1	1	1	2921.0 ab
3. Cloransulam	35	1	1	1	2937.2 ab
4. Cloransulam	40	1	1	1	2946.7 ab
5. Chlorimuron/3	20	4	1	1	2194.7 c
6. Unweeded control	–	1	1	1	1610.0 d
7. Weeded control	–	1	1	1	3065.0 a
Fcal	–	–	–	–	36.73*
LSD (least significant difference) (10%)	–	–	–	–	365.34
CV (%)	–	–	–	–	6.70

– /1 DAA = days after application; – Application with Agral™/2 (0.2% v/v) and Joint Oil™/3 (0.5% v/v). – Means followed by the same letter in the column do not differ by Tukey's test (p≤ 0.10). * = significant.

Conclusions

Herbicide cloransulam-methyl (Pacto™) has satisfactorily controlled *Conyza bonariensis* when applied in postemergence at doses of 35 and 40 g a.i. ha^{-1}, not differing significantly from chlorimuron-ethyl (20 g a.i. ha^{-1}), and also not causing symptoms of injuries and reduced productivity in SYN 1059 RR Vtop™ soybean crop.

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