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HERBICIDE PERFORMANCE IN THE CONTROL OF *Conyza* spp. WHERE THREE PLANT HEIGHTS

Theodoro SCHNEIDER[1], Juliane Nicolodi CAMERA[1], Jana KOEFENDER[1], Mauro Antônio RIZZARDI[2], Mario Antônio BIANCHI[3], Ana Paula ROCKENBACH[4]

[1] Center for Health and Agrarian Sciences, University of Cruz Alta, Cruz Alta, Rio Grande do Sul, Brazil.
[2] Faculty of Agronomy and Veterinary, University of Passo Fundo, Passo Fundo, Rio Grande do Sul, Brazil.
[3] CCGL Technology, Cruz Alta, Rio Grande do Sul, Brazil.
[4] Private Practice, Passo Fundo, Rio Grande do Sul, Brazil.

Corresponding author:
Theodoro Schneider
Email: theodoroschneider@hotmail.com

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Abstract
Intensive use of the herbicide glyphosate has led to herbicide resistant *Conyza* spp. populations. Thus, there is a need to indicate alternative herbicides and the appropriate developmental stage for controlling these populations. This study identifies alternatives for controlling glyphosate-resistant horseweed, with treatment applications at different plant heights. For this purpose, field experiments were conducted in the 2016/17 and 2017/18 crop years. The evaluated treatments were: glyphosate (540 g ae ha^{-1}), glyphosate (1080 g ae ha^{-1}), glyphosate (2160 g ae ha^{-1}), glyphosate (3240 g ae ha^{-1}), glyphosate + 2.4-D (1080 + 1005 g ae ha^{-1}), glyphosate + saflufenacil (1080 + 49 g ae/ai ha^{-1}), paraquat (400 g ai ha^{-1}), diquat (400 g ai ha-1), ammonium glufosinate (600 g ai ha^{-1}), and control (without application). These treatments were applied to plants with a maximum of 5 cm; plants between 6 and 15 cm; and plants between 16 and 25 cm. The results showed that glyphosate did not control weeds, regardless of rate. With the exception of 2,4-D, which needs complementation with sequential application of another contact herbicide, all alternatives were viable for the control of *Conyza* spp. plants with a maximum height of 5 cm.

Keywords: Alternative Chemical Control. Application Growth Stage. Horseweed. Resistance.

1. Introduction

Weed management in soybean has been facilitated since the introduction of Roundup Ready® (RR) technology, which confers resistance to the herbicide glyphosate. However, exclusive use of this herbicide, applied continuously and more than twice during the growing season, has led to resistant and tolerant weeds (Vargas et al. 2007; Vargas et al. 2013; Heap 2018).

The genus *Conyza* includes approximately 50 species, which are distributed almost worldwide (Kissmann and Groth 1999). The most prominent species in terms of their negative character are *C. bonariensis*, *C. canadensis*, and *C. sumatrensis*, popularly known in Brazil as “buva” (horseweed). These species show a gradual increase of infestation in the agricultural areas of Brazil, especially those cultivated with soybean, becoming, together with *Digitaria insularis* (sourgrass), one of the main weeds of this crop. Among the main characteristics of these species stand out wide ecological adaptability; large seed production (up to 200 thousand per plant); seed dispersion, which can exceed 100 meters away from the mother plant; broad adaptability to soil conservation systems; and the evolution of glyphosate-resistant biotypes (Wu and Walker 2004; Crose et al. 2020).

Glyphosate, an enolpyruvyl shikimate-phosphate synthetase (EPSPS) inhibitor herbicide, has been widely adopted as the main form of chemical control of weeds, especially horseweed. The flexibility of this molecule favored its use in pre-sowing of soybean and in postemergence of soybean RR crop, which led to the selection of glyphosate-resistant horseweed biotypes. Resistance is the inherent and inheritable ability of certain biotypes within a population to survive and reproduce after exposure to herbicide rates that would be lethal to susceptible individuals of the species (Christoffoleti et al. 2016).

Horseweed then began to cause high damage to soybean due to control failures caused by resistance. For *C. bonariensis*, the more advanced its stage of development at the time of soybean sowing, the greater will be the crop yield losses due to the difficulty of their management (Patel et al. 2010). Also, the more advanced the stage of development of *C. bonariensis*, the lower the efficiency of chemical control. In this regard, plants showing up to six leaves correspond to the ideal stage for chemical management (Kaspary 2014). Thus, horseweed management requires the adoption of alternative control methods. In this sense, the use of herbicides with a mechanism of action distinct from glyphosate is one of the main tools.

In general, horseweed control failures in the field are associated with advanced stage of development at the time of application, besides the use of inefficient herbicides (Vangessel et al. 2009; Crose et al. 2020). The more advanced the stage of weed development, the greater the ability of the herbicide to metabolize and degrade, causing lateral sprouts and lack of control (Singh and Singh 2004; Moreira et al. 2010). Herbicide translocation to all parts of the plant also decreases at advanced stages of development, interfering with product efficiency (Shrestha et al. 2007).

Measures to control resistant populations need to be adopted and can be performed by applying herbicides whose mechanism of action differs from that of glyphosate. The association of herbicides and the use of herbicides with different mechanisms of action are recommended measures for integrated weed management (Shaner 2000; Johnson and Gibson 2006). Many herbicides used in pre-sowing of soybean are efficient alternatives to control glyphosate-resistant horseweed populations. Manly because they are from differents mechanims of action, among these, paraquat (Photosystem I Inhibitor - PS I), 2,4-D (Synthetic Auxins), ammonium glufosinate (Glutamine Sinthetase Inhibitor - GS), and saflufenacil (Protoporphyrinogen Oxidase Inhibitor - PPO) have proved efficiency (Bianchi et al. 2011; Kaspary 2014).

The indication of alternative herbicides and the appropriate developmental stage for glyphosate-resistant horseweed control is important for the implementation of integrated weed management practices. Thus, this study seeks to characterize the response of *Conyza* spp. resistant to glyphosate to herbicides with mechanism of action distinct applied at different plant heights.

2. Material and Methods

To achieve the proposed objectives, two field experiments were conducted in the Universidade de Cruz Alta experimental area, from November to December 2016 and from October to November 2017. The experimental area is located at a latitude of 28º33'41,30" S and a longitude of 53º37'18,61" O, with an average altitude of 444 m.

Experimental conditions were the same in both cases and were denominated Trial I and Trial II. The experimental design was a randomized complete block design with four replications, arranged in a split-plot scheme, with each experimental unit occupying an area of 12m² (3m x 4m). The plots consisted of herbicide treatments with different mechanisms of action, applied either alone or in combination with glyphosate (Table 1); and subplots consisted of different horseweed heights: Height I - plants up to 5 cm; Height II - plants between 6 and 15 cm; and Height III - plants between 16 and 25 cm.

Table 1. Herbicidal treatments, with their respective mechanisms of action, active ingredient and label applied. Cruz Alta - 2016 e 2017.

TTreat	Mechanisms of action		Active ingredients		Label (g a.i. or a.e. ha^{-1})
1[1]	EPSPs Inhib.	---	Glyphosate	---	540
221	EPSPs Inhib.	---	Glyphosate	---	1080
131	EPSPs Inhib.	---	Glyphosate	---	2160
441	EPSPs Inhib.	---	Glyphosate	---	3240
551	EPSPs Inhib.	Auxin Mimic	Glyphosate	2,4-D	1080 + 1005
661	EPSPs Inhib.	PROTOX Inhib.	Glyphosate	Saflufenacil	1080 + 49
771	Photosystem I Inhib.	---	Paraquat	---	400
881	Photosystem I Inhib.	---	Diquat	---	400
991	Glutamine Synthetase Inhib.	---	Ammonium Glufosinate	---	600
1101	Check	---	---	---	---

Source: Agrofit, 2018. [1]All treatments except the check, the adjuvant Assist (0,5% v/v) was added.

In the experiment conducted in 2016 (Trial I), treatments were applied on 11/25/2016. In the second experiment (Trial II), conducted in 2017, treatments were applied on 10/20/2017. Herbicides were applied with the aid of a precision CO_2 pressurized backpack sprayer equipped with TT 110.015 nozzles, with a syrup volume of 100L ha^{-1}. Climatic conditions during application in the experiments are described in Table 2.

Table 2. Climatic conditions at the time of applications of treatments in the two years of the trial. University of Cruz Alta, Cruz Alta, RS, Brazil, 2016 e 2017.

Year	Temperature	Relative humidity	Wind speed
1° (2016)	28 °C	35%	5 km/h
2° (2017)	20 °C	75%	6 km/h

Plants and their heights were determined at the time of the first evaluation. For this purpose, 10 plants per plot were marked with toothpicks. The same evaluation pattern was used on subsequent evaluations on the same plants, aiming to obtain the lowest possible variability. The evaluated variable was control at 7, 14, 21, and 28 days after the application of treatments (DAT), using a percentage scale where zero (0) represents no symptoms and one hundred (100) represents plant death (Frans et al. 1986). Subsequently, the data obtained were analyzed for normality and homoscedasticity, and then submitted to analysis of variance ($p \leq 0.05$). In case of statistical significance, the means were compared by the Scott-Knott test ($p \leq 0.05$).

3. Results and Discussion

The results showed differences in the field control of horseweed among the herbicides tested (Tables 3, 4, 5, and 6) in both trials (2016 and 2017). The isolated application of the herbicide glyphosate in the four rates tested in the experiments did not provide a satisfactory control of horseweed in any evaluation period (Tables 3, 4, 5, and 6). Regarding the stage of development, glyphosate application alone was statistically the same at the three developmental stages, at the four evaluation times.

The results of Trial I, conducted in 2016, point to a satisfactory control at 7 days after the application of treatments (DAT) glyphosate + saflufenacil, paraquat, diquat, and ammonium glufosinate when applied to plants with a maximum height of 5 cm (Table 3). At 14 DAT, plants up to 5 cm in height remained with the same efficiency pattern as at 7 DAT between treatments. Plants between 6 and 15 cm in height were controlled with glyphosate + saflufenacil and ammonium glufosinate (Table 3). Rapid control of young plants is mainly due to the mode of action of these herbicides, both with contact action and fast necrosis effect on plant leaf tissue (Shaner 2014).

Table 3. Control (%) of *Conyza* spp. at 7 and 14 days after applications of treatments (DAT) in the trial I (2016). Cruz Alta – 2017.

Herbicides (g a.e./a.i. ha^{-1})	Plant Height		
	Up to 5 cm	6 to 15 cm	16 to 25 cm
		7 DAT	
Glyphosate (540)	6.2^{Ae}	6.2^{Ae}	6.2^{Ae}
Glyphosate (1080)	11.7^{Ad}	9.7^{Ae}	9.7^{Ae}
Glyphosate (2160)	11.0^{Ad}	8.0^{Ae}	8.0^{Ae}
Glyphosate (3240)	11.7^{Ad}	9.0^{Ae}	8.0^{Ae}
Glyphosate + 2,4-D (1080 + 1005)	38.7^{Ac}	20.0^{Bd}	20.0^{Bd}
Glyphosate + Saflufenacil (1080 + 49)	100.0^{Aa}	87.5^{Ba}	82.0^{Ca}
Paraquat (400)	90.0^{Ab}	71.7^{Bc}	63.2^{Cc}
Diquat (400)	100.0^{Aa}	80.0^{Bb}	73.0^{Cb}
Ammoniun glufosinate (600)	98.2^{Aa}	85.0^{Ba}	80.0^{Ca}
Check	00.0^{Af}	00.0^{Af}	00.0^{Af}
C.V. (%)		8.45	
		14 DAT	
Glyphosate (540)	6.0^{Ac}	03.2^{Ae}	2.7^{Ad}
Glyphosate (1080)	12.5^{Ac}	07.0^{Ae}	5.5^{Ad}
Glyphosate (2160)	9.0^{Ac}	04.7^{Ae}	4.0^{Ad}
Glyphosate (3240)	10.0^{Ac}	06.7^{Ae}	5.0^{Ad}
Glyphosate + 2,4-D (1080 + 1005)	73.7^{Ab}	47.5^{Bd}	40.0^{Bc}
Glyphosate + Saflufenacil (1080 + 49)	100.0^{Aa}	97.5^{Ab}	82.5^{Ba}
Paraquat (400)	95.2^{Aa}	73.2^{Bc}	61.2^{Bb}
Diquat (400)	98.7^{Aa}	75.0^{Bc}	60.0^{Cb}
Ammoniun glufosinate (600)	99.0^{Ba}	100.0^{Aa}	72.0^{Ca}
Check	00.0^{Ac}	00.0^{Ae}	00.0^{Ad}
C.V. (%)		23.5	

Note: Averages followed by the same lowercase later in the columm or uppercase in the row, compared in each evaluation period, do not differ statistically from each other by the Scott-Knott test (p≤0,05).

In the evaluation performed at 21 DAT, the application of glyphosate + 2,4-D was incorporated into the group of treatments that showed efficiency in plants up to 5 cm (Table 4). In the last evaluation, performed at 28 DAT, the efficiency of the treatment glyphosate + 2,4-D decreased and treatments glyphosate + saflufenacil, paraquat, diquat, and glufosinate ammonium remained efficient, revealing that glyphosate + 2,4-D needs complementation with sequential application of another contact action herbicide.

When comparing the efficiency of treatments in relation to the developmental stage of plants, only treatments glyphosate + saflufenacil and ammonium glufosinate were efficient in plants between 6 and 15 cm in height. Although these treatments had a control equal to or greater than 80% in plants between 16 and 25 cm in height, it is noteworthy that the plants were not fully controlled and subsequently sprouted. In case soybean was sown in this period, these plants would compete with the crop at an advanced stage of development and without postemergence control alternatives.

Products with contact action require greater herbicide coverage area, a fact that is difficult in plants at an advanced stage of development. In this way, plants regrow laterally, surviving and competing in the future with the subsequent crop (Moreira et al. 2010).

Table 4. Control (%) of *Conyza* spp. at 21 and 28 days after applications of treatments (DAT) in the trial I (2016). Cruz Alta – 2017.

Herbicides (g a.e./a.i. ha^{-1})	Plant Height		
	Up to cm	6 to 15 cm	16 to 25 cm
		21 DAT	
Glyphosate (540)	5.5^{Ac}	2.5^{Ac}	1.2^{Ac}
Glyphosate (1080)	11.7^{Ac}	5.5^{Ac}	5.0^{Ac}
Glyphosate (2160)	6.0^{Ac}	1.5^{Ac}	1.2^{Ac}
Glyphosate (3240)	9.0^{Ac}	4.7^{Ac}	4.0^{Ac}
Glyphosate + 2,4-D (1080 + 1005)	91.0^{Ab}	63.7^{Bb}	46.2^{Cc}
Glyphosate + Saflufenacil (1080 + 49)	100.0^{Aa}	100.0^{Aa}	86.7^{Ba}
Paraquat (400)	98.0^{Aa}	68.2^{Bb}	53.2^{Cb}
Diquat (400)	92.5^{Ab}	66.2^{Bb}	50.0^{Cb}
Ammoniun glufosinate (600)	100.0^{Aa}	97.2^{Aa}	87.5^{Ba}
Check	00.0^{Ac}	00.0^{Ac}	00.0^{Ac}
C.V. (%)		13.58	
		28 DAT	
Glyphosate (540)	3.5^{Ac}	1.5^{Ac}	0.0^{Ac}
Glyphosate (1080)	8.5^{Ac}	5.5^{Ac}	1.7^{Ac}
Glyphosate (2160)	4.2^{Ac}	2.2^{Ac}	0.0^{Ac}
Glyphosate (3240)	3.0^{Ac}	0.5^{Ac}	0.0^{Ac}
Glyphosate + 2,4-D (1080 + 1005)	82.5^{Ab}	60.0^{Bb}	33.7^{Cb}
Glyphosate + Saflufenacil (1080 + 49)	100.0^{Aa}	98.7^{Aa}	83.7^{Ba}
Paraquat (400)	100.0^{Aa}	56.2^{Bb}	36.5^{Cb}
Diquat (400)	100.0^{Aa}	55.0^{Bb}	38.7^{Cb}
Ammonium glufosinate (600)	100.0^{Aa}	98.5^{Aa}	85.0^{Ba}
Check	00.0^{Ac}	00.0^{Ac}	00.0^{Ac}
C.V. (%)		17.72	

Note: Averages followed by the same lowercase later in the columm or uppercase in the row, compared in each evaluation period, do not differ statistically from each other by the Scott-Knott test (p≤0,05).

From the results obtained in Trial I, it must be highlighted that although the treatment glyphosate + 2,4-D provided more than 90% control at 21 DAT, this value decreased to 82% at 28 DAT, emphasizing that only this application needs supplementation to kill horseweed plants. Treatments with the application of contact action herbicides alone controlled 100% of plants up to 5 cm at 28 DAT. However, for plants at most advanced stages, treatment efficiency decreased in the last two evaluations. For this reason, application of these herbicides should not be recommended to horseweed plants higher than 10 cm, due to the high risk of plant regrowth and high pressure on the herbicide, which will accelerate the selection of resistant populations.

The weather conditions of Experiment I, conducted in 2016, were not ideal at the time of herbicide application. The temperature was 28 °C and the relative humidity 35%. Herbicide application under relative humidity below 40% and temperature above 27.5 °C is considered unfavorable (Theisen and Ruedell 2004).

Trial II, conducted in 2017, showed similar results for treatments with application of the herbicide glyphosate alone. Although horseweed plants of up to 5 cm showed mild symptoms, there was no statistical difference between the four glyphosate rates tested and the three stages of development, at the four evaluation times (Tables 5 and 6). These results suggest that the horseweed populations present in the experimental area were glyphosate resistant.

Table 5. Control (%) of *Conyza* spp. at 7 and 14 days after application of treatments (DAT), in the trial II (2017). Cruz Alta – 2017.

Herbicides (g a.e./a.i. ha^{-1})	Plant Height		
	Up to 5 cm	6 to 15 cm	16 to 25 cm
		7 DAT	
Glyphosate (540)	3.5^{Ac}	1.5^{Ac}	0.0^{Ac}
Glyphosate (1080)	8.5^{Ac}	5.5^{Ac}	1.7^{Ac}
Glyphosate (2160)	4.2^{Ac}	2.2^{Ac}	0.0^{Ac}
Glyphosate (3240)	3.0^{Ac}	0.5^{Ac}	0.0^{Ac}
Glyphosate + 2.4-D (1080 + 1005)	62.5^{Ab}	50.0^{Bb}	33.7^{Cb}
Glyphosate + Saflufenacil (1080 + 49)	100.0^{Aa}	98.7^{Aa}	83.7^{Ba}
Paraquat (400)	100.0^{Aa}	56.2^{Bb}	36.5^{Cb}
Diquat (400)	100.0^{Aa}	55.0^{Bb}	38.7^{Cb}
Ammoniun glufosinate (600)	100.0^{Aa}	98.5^{Aa}	85.0^{Ba}
Check	00.0^{Ac}	000.0^{Ac}	00.0^{Ac}
C.V. (%)		4.20	
		14 DAT	
Glyphosate (540)	3.5^{Ac}	1.2^{Ad}	0.5^{Ae}
Glyphosate (1080)	3.5^{Ac}	1.7^{Ad}	0.7^{Ae}
Glyphosate (2160)	4.5^{Ac}	2.7^{Ad}	1.7^{Ae}
Glyphosate (3240)	7.2^{Ac}	5.0^{Ad}	4.0^{Ae}
Glyphosate + 2,4-D (1080 + 1005)	65.0^{Ab}	45.0^{Bc}	36.2^{Bd}
Glyphosate + Saflufenacil (1080 + 49)	99.2^{Aa}	88.7^{Bb}	68.7^{Cb}
Paraquat (400)	99.7^{Aa}	86.2^{Bb}	52.5^{Cc}
Diquat (400)	100.0^{Aa}	98.7^{Aa}	90.7^{Aa}
Ammonium glufosinate (600)	100.0^{A}a	98.0^{Aa}	93.0^{Aa}
Check	00.0^{Ac}	00.0^{Ad}	00.0^{Ae}
C.V. (%)		14.72	

Note: Averages followed by the same lowercase later in the columm or uppercase in the row, compared in each evaluation period, do not differ statistically from each other by the Scott-Knott test (p≤0,05).

The treatment with application of glyphosate + 2,4-D controlled weeds faster in Experiment II compared to trial I for the three plant heights. Notwithstanding, the recovery capacity of horseweed plants was higher in the experiment conducted in 2017, mainly due to the higher water availability in that year. These results confirm the need for treatment complementation as suggested in the presentation of results of Experiment I. The application of glyphosate + 2,4-D alone at the time of desiccation resulted in the presence of 13 horseweed plants m^{-2} at soybean sowing, with plants averaging 20 cm in height. In treatments with paraquat + diuron supplementation, these values were equal to zero (Oliveira Neto et al. 2010).

For the other treatments (glyphosate + saflufenacil, paraquat, diquat, and ammonium glufosinate), plants up to 5 cm were fully controlled at 7 DAT. This result remained until 28 DAT, when the last evaluation was performed, except for glyphosate + saflufenacil, in which some plants started to regrow at 21 DAT. There were differences between treatments regarding the control at different developmental stages. For plants with height between 6 and 15 cm, the treatment with the best results, considering the whole evaluation period, was ammonium glufosinate (Tables 5 and 6). The treatment glyphosate + saflufenacil controlled 98.7% of plants at 7 DAT. However, this value decreased to 77.5% in the last evaluation due to regrowth of horseweed plants. The herbicide diquat slowly controlled horseweed plants, but was consistent until 28 DAT. At 7 DAT, it presented 55% control, increasing to 98.7% at 14 DAT and ending with 98.2 at 28 DAT.

Table 6. Control (%) of *Conyza* spp. at 21 and 28 days after treatments applications (DAT), in the trial II (2017). Cruz Alta – 2017.

Herbicides (g a.e./a.i. ha^{-1})	Plant Height		
	Up to 5 cm	6 to 15 cm	16 to 25 cm
		14 DAT	
Glyphosate (540)	5.2^{Ad}	3.0^{Ae}	1.5^{Af}
Glyphosate (1080)	3.5^{Ad}	2.2^{Ae}	0.5^{Af}
Glyphosate (2160)	6.5^{Ad}	4.0^{Ae}	2.0^{Af}
Glyphosate (3240)	6.7^{Ad}	4.0^{Ae}	2.5^{Af}
Glyphosate + 2.4-D (1080 + 1005)	68.7^{Ac}	47.5^{Bd}	38.7^{Ce}
Glyphosate + Saflufenacil (1080 + 49)	94.5^{Ab}	80.5^{Bb}	60.0^{Cc}
Paraquat (400)	97.5^{Aa}	72.5^{Bc}	45.0^{Cd}
Diquat (400)	100.0^{Aa}	99.5^{Aa}	85.5^{Bb}
Ammoniun glufosinate (600)	100.0^{Aa}	99.2^{Aa}	93.2^{Ba}
Check	00.0^{Ae}	00.0^{Ae}	00.0^{Af}
C.V. (%)		6.74	
		28 DAT	
Glyphosate (540)	3.5^{Ac}	1.7^{Ad}	00.5^{Ae}
Glyphosate (1080)	3.2^{Ac}	2.2^{Ad}	00.5^{Ae}
Glyphosate (2160)	5.7^{Ac}	2.7^{Ad}	01.0^{Ae}
Glyphosate (3240)	5.6^{Ac}	2.6^{Ad}	01.9^{Ae}
Glyphosate + 2,4-D (1080 + 1005)	76.2^{Ab}	63.7^{Bc}	41.2^{Cd}
Glyphosate + Saflufenacil (1080 + 49)	96.5^{Aa}	77.5^{Bd}	47.0^{Cc}
Paraquat (400)	98.7^{Aa}	66.2^{Bc}	40.0^{Cd}
Diquat (400)	100.0^{Aa}	98.2^{Aa}	82.5^{Bb}
Ammoniun glufosinate (600)	100.0^{Aa}	97.5^{Aa}	90.5^{Ba}
Check	00.0^{Ac}	00.0^{Ad}	00.0^{Ae}
C.V. (%)		7.84	

Note: Averages followed by the same lowercase later in the columm or uppercase in the row, compared in each evaluation period, do not differ statistically from each other by the Scott-Knott test (p≤0,05).

For plants with a height of 16 to 25 cm, only ammonium glufosinate showed a control above 90%; however, the control was limited to 90.5% at 28 DAT with the beginning of regrowth of plants at this stage of development. Thus, none of the treatments can be used alone in the control of plants higher than 16 cm.

The higher efficiency of some treatments in trial II, conducted in 2017, may be mainly due to better weather conditions at the time of application. The temperature was 20 °C and the relative humidity 75%. These conditions are considered ideal for herbicide application (Theisen and Ruedell 2004).

Glyphosate-resistant *Conyza sumatrensis* biotypes up to 7 cm in height were controlled at 14 DAT with ammonium glufosinate, paraquat + diuron, and glyphosate + ammonium glufosinate; at 21 DAT, treatments 2,4-D and glyphosate + 2,4-D are added to the group (Santos et al. 2015; Mcauley et al. 2019). Pre-flowering horseweed plants were only controlled (above 90%) at 28 DAT with the application of ammonium glufosinate associated with MSMA; bromacil + diuron; and metsulfuron (Moreira et al. 2010; Zimmer et al. 2018).

The stage of development is directly related to susceptibility to herbicides, mainly contact products. *Conyza canadensis* biotypes showed different glyphosate resistance levels as a function of developmental stage (Shrestha et al. 2007). Thus, application of herbicides in the early stages of horseweed development is essential for a successful control. In applications at early stages of development, the susceptibility to herbicides is higher, leading to lower risk of plant regrowth. At advanced stages, with increased dry matter accumulation, plants acquire greater capacity to survive and recover from the effects of herbicides (Carvalho et al. 2008; Moreira et al. 2010; Zimmer et al. 2018).

Treatments that provided between 80 and 90% control are not satisfactory enough. Due to the large capacity of seed production of horseweed plants (around 200,000 seeds per plant), only the total control of plants will prevent the propagation of seeds of the species to the area itself or even to distant regions.

It is worth mentioning the importance of adopting year-round management strategies in agricultural areas. The use of cover crops in the winter along with the application of herbicides are alternatives that facilitate control in pre-sowing of soybean. These strategies help to reduce the density and height of horseweed plants at the time of desiccation (Oliveira Neto et al. 2010; Mcauley et al. 2019). Together with these alternatives, there are numerous efficient chemical control alternatives to be used in pre-sowing of soybean, especially in horseweed plants at early stages of growth.

4. Conclusions

Thus, with the results obtained in this study, we conclude that horseweed plants with a maximum of 5 cm are efficient by applying the herbicides glyphosate + saflufenacil, paraquat, diquat and ammonium glufosinate; Plants with a height between 6 and 15 cm are effectively controlled with the herbicide treatments glyphosate + saflufenacil, diquat and glufosinate ammonium, presenting inefficient control with the other treatments; and horseweed plants with 16 to 25 cm are controlled only with treatment with ammonium glufosinate.

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