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Article

Sumatran Fleabane Control using Glyphosate in Association with Halauxifen-Methyl Formulations

Controle de Buva com Glyphosate em Associação com Formulações de Halauxifen-Methyl

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ABSTRACT - The effectiveness of a new product has a great importance to weed control, especially those that are difficult to control or resistant to, such as the sumatran fleabane (*Conyza sumatrensis*). The objective of this research was to evaluate the control of *C. sumatrensis* at different growth stages, using halauxifen-methyl in combination with other herbicides. The experimental design used was a randomized blocks in a 3x10 factorial scheme, with four replications. The plants of *C. sumatrensis* were evaluated at different growth: stage 1: plants with 8 leaves; Stage 2: plants with 19 leaves and stage 3: plants with 45 leaves fully expanded. The herbicides used were the association of glyphosate with the herbicides 2,4-D at 806, 943 and 1,209 g a.e. ha^{-1}, halauxifen-methyl + diclosulam at 5.06 g a.e. ha^{-1} + 25.52 g a.i. ha^{-1} and 6.32 g a.e. ha^{-1} + 31.87 g a.i. ha^{-1}, halauxifen-methyl + 2,4-D at 5.00 + 783 g a.e. ha^{-1} and 6,0 + 940 g a.e. ha^{-1} and halauxifen-methyl at 5.0 and 6.0 g a.e. ha^{-1} and untreated, totaling 10 treatments. The herbicides demonstrated satisfactory control of the plants in Stage 1 at 50 DAA, with the exception of the glyphosate + 2,4-D treatment at the lowest rate. However for Stages 2 and 3 the halauxifen-methyl + diclosulam in both rates, provided superior controls in relation to the other treatments. The control of sumatran fleabane was facilitated when their management occurs in the early stages of development, however independent of the development stage, the best controls obtained were with the treatment containing glyphosate + halauxifen-methyl + diclosulam at 1,440 g a.e. ha^{-1} + 6.32 g a.e. ha^{-1} + 31.87 g a.i. ha^{-1}. Thus, combinations of herbicides containing halauxifen-methyl are another option to control *C. sumatrensis* in agricultural systems.

Keywords: *Conyza sumatrensis*, arylpicolinate herbicide, auxin mimic herbicide, burndown.

*RESUMO - A confirmação da efetividade de novos produtos é de grande importância para o controle de plantas daninhas, principalmente aquelas de difícil controle ou resistentes, como o caso da buva (**Conyza sumatrensis**). O objetivo deste trabalho foi avaliar o controle de **C. sumatrensis** em diferentes estádios de desenvolvimento, utilizando-se halauxifen-methyl em associação com outros princípios ativos de herbicidas. O delineamento experimental utilizado foi de blocos ao acaso, em esquema fatorial 3x10, com quatro repetições. As plantas de **C. sumatrensis** foram divididas em três estádios de desenvolvimento: estádio 1: plantas com 8 folhas, estádio 2: plantas com 19 folhas e estádio 3: plantas com 45 folhas totalmente expandidas. Os tratamentos consistiram da associação de glyphosate (1.440 g ha^{-1}) com os herbicidas 2,4-D a 806, 943 e 1.209 g e.a. ha^{-1}, halauxifen-methyl + diclosulam at 5,06 g e.a. ha^{-1} + 25,52 g i.a. ha^{-1} and 6,32 g e.a. ha^{-1} + 31,87 g i.a. ha^{-1}, halauxifen-methyl + 2,4-D at 5,00 + 783 g e.a. ha^{-1} and 6,0 +*

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940 g e.a. ha^{-1} and halauxifen-methyl at 5.0 and 6.0 g e.a. ha^{-1}, além de testemunha sem aplicação, totalizando 10 tratamentos. Os herbicidas apresentaram controle satisfatório das plantas de buva no estádio 1 aos 50 DAA, com exceção do tratamento glyphosate + 2,4-D, na dose mais baixa. Contudo, para os estádios 2 e 3 o halauxifen-methyl + diclosulam, em ambas as doses, proporcionou controles superiores em relação aos demais tratamentos. O controle de ***C. sumatrensis*** *foi facilitado quando manejado em estádios iniciais de desenvolvimento; entretanto, independentemente do estádio de desenvolvimento, os melhores controles foram com o tratamento contendo glyphosate + halauxifen-methyl + diclosulam a 1.440 g e.a. ha^{-1} + 6.32 g e.a. ha^{-1} + 31.87 g i.a. ha^{-1}. Assim, as associações de herbicidas contendo halauxifen-methyl são mais uma opção para o manejo de* ***C. sumatrensis*** *nos sistemas agrícolas.*

Palavras-chave: *Conyza sumatrensis*; herbicidas arylpicolinato; herbicidas mimetizadores de auxina; dessecação.

INTRODUCTION

Since the 1940's, multiple classes of auxin herbicides were developed, which revolutionizing agricultural practices and weed management (Troyer, 2001). The classic synthetic auxins herbicide is the 2,4-D, with a structure similar to the indole-3-acetic acid (IAA), its exogenous application promotes hormonal unbalance in plants, increasing the 1-aminocyclopropane-1-carboxylic acid synthesis production, which, increases the production of ethylene, thus resulting ilant's death (Grossmann, 2010).

New auxin herbicides have been developed, such as the halauxifen-methyl, the first active ingredient of the chemical group arylpicolinate. The halauxifen-methyl may be uptaken by the leaves and translocated through the phloem and the xylem, accumulating in the meristematic tissue. It also degrades quickly in the soil and in the straw and has a broad control spectrum in broadleaf weeds (EFSA, 2015). The symptoms are similar to other auxin herbicides: hyponastic response, deformation, necrosis and eventual death.

The auxin transport is complex and highly regulated, involving many proteins (Woodward and Bartel, 2005). The 2,4-D auxin receptors include the F-Box (TIR1/AFB$^{1-5}$) family members (Grossmann, 2010). The halauxifen-methyl, on the other hand, presents a higher degree of interaction with the AFB5 (Auxin F-Box) protein (Bell, 2014) as well picloram (Walsh et al., 2006; Calderón et al., 2012). However, like other auxin herbicides (picloram, 2,4-D, fluroxypyr e quinclorac), it also interacts with the TIR1 protein (Lee et al., 2014).

Currently, the *Conyza* spp. is the most prominent weed species present in the Brazilian agricultural system. The use of auxin herbicides is essential for its effective control as well the applications in early development stages (Constantin et al., 2013). Glyphosate resistant hairy fleabane and sumatran fleabane biotypes resistant to glyphosate and chlorimuron were identified in the State of Paraná (Santos et al., 2014a), making it harder for the agricultural system to control the species. So, herbicides like the auxins, with affinities to distinct locations in the metabolic path, may reduce the risk to select resistant biotypes. For instance, the halauxifen-methyl herbicide may be an effective new tool to manage resistant weeds, due to its higher affinity to the AFB5 protein.

Our objective was to evaluate the sumatran fleabane control in various development stages, using glyphosate in association with 2,4-D, halauxifen-methyl and formulations containing halauxifen-methyl+diclosulam and halauxifen-methyl+2,4-D.

MATERIAL AND METHODS

The field experiment was carried out in Toledo (PR) (24°67'86.7" S; 53°78'86.8" W), from 06/27/2016 to 09/02/2016. The soil in the experimental site was classified as Clay Latosol (713 g kg^{-1} clay, 144 g kg^{-1} silt, 143 g kg^{-1} sand). The area's predominant climate is the Cfa in Köppen climate classification – humid subtropical, with hot summers, rare occurrence of frost and rain tending to concentrate along the southern hemisphere summer. During the warm months, the average temperature is higher than 22 ºC. During the cold months, the temperatures fall below 13 ºC. The average annual rainfall ranges from 1600 to 1800 mm (IAPAR, 2014). Local rainfall data for the field study period are presented in Figure 1.

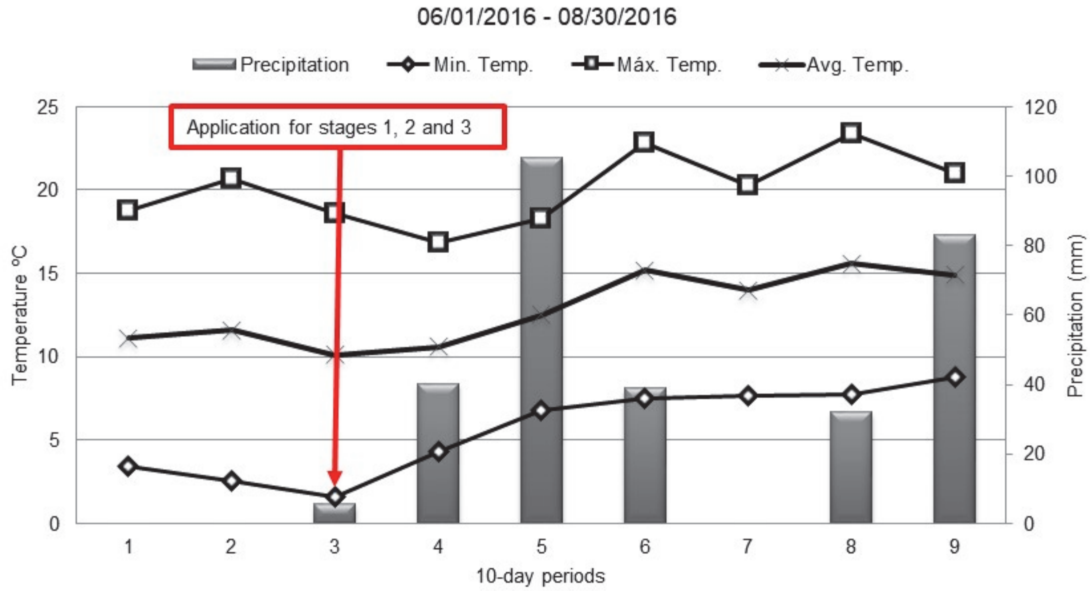


Figure 1 - Cumulative precipitation data for the experiment period in. Toledo (PR), 2016.

The experiment used was a randomized complete block arranged in a 3x10 (AxB) factorial design, with four repetitions. The sumatran fleabane plants (*Conyza sumatrensis*) were classified into three development stages, forming the factor A. Stage 1 was composed by plants with eight (8) leaves on average, 5 to 10 cm of height and 16 plants m^{-2} density. Stage 2 was composed by plants with nineteen (19) leaves on average, 10 to 20 cm of height and 23 plants m^{-2} density. Finally, stage 3 was composed by plants with forty-five (45) leaves on average, 20 to 30 cm of height and a 34 plants m^{-2} density. The factor B was represented by a various herbicide treatments and their respective rates, as described in Table 1. The herbicides and combinations used were glyphosate with 2,4-D, halauxifen-methyl + diclosulam, halauxifen-methyl + 2,4-D and halauxifen-methyl straight.

Immediately before application, ten plants representative of each stage were marked for posterior evaluation. Each experimental unit comprised a 4.0 meters wide by 5.0 meters long area. In each plot, 0.5 meter were excluded from both extremities, resulting in a 15 m^2 working area.

Table 1 - Treatments evaluated in the sumatran fleabane control experiment. Toledo (PR), 2016

Treatment	Rate (g a.e. ha^{-1})
1. Glyphosate + 2,4-D	1,440 + 806
2. Glyphosate + 2,4-D	1,440 + 943
3. Glyphosate + 2,4-D	1,440 + 1,209
4. Glyphosate + [halauxifen-methyl® + diclosulam] (1)	1,440 + [5.06+25,52]*
5. Glyphosate + [halauxifen-methyl® + diclosulam]	1,440 + [6.32+31,87]*
6. Glyphosate + [halauxifen-methyl® + 2,4-D] (1)	1,440 + [5.00+783]*
7. Glyphosate + [halauxifen-methyl® + 2,4-D]	1,440 + [6.00+940]*
8. Glyphosate + [halauxifen-methyl®]	1,440 + [5.00]*
9. Glyphosate + [halauxifen-methyl®]	1,440 + [6.00]*
10. Untreated	-

® Dow Agrosciences, Indianapolis, IN-USA (1) Formulação pronta em fase de registro. * A ester methylated soybean oil based adjuvant was added, at a 0,1% v v^{-1} dosage.

The herbicide applications were carried out using a backpack CO_2 pressure sprayer under 36 lb pol^{-2}, equipped with a six AIXR 110.015 tips bar, spaced by 0.5 m (resulting in a 3 meters application range). This setup allows an output volume of 100 L ha^{-1} rate. During the application, the soil was humid, the air temperature varied between 23 and 27 °C, the relative humidity was 62% and the winds varied between 1.2 and 1.9 km h^{-1}.

The sumatran fleabane control level was evaluated simultaneously for all plants, considering the distinct development stages previously selected (factor A). Evaluation occurred at 5, 10, 15, 20, 25, 30, 35, 40, 45 and 50 DAA (Days After [herbicide] Application). This evaluation was carried out by visual inspection, classifying each plant in a scale ranging from 0 to 100%, 0% meaning that the plant presents no symptom and 100% meaning the plant is dead (SBCPD, 1995). The control evaluation was carried out taking as reference the area infestation, calculated from the existing weed samples in the non-sprayed untreated area.

At 60 DAA, the shoot of ten marked plants of each plot were collected, packed in paper bags and placed in a air circulating greenhouse, until a constant weight was obtained. Afterwards, the plants were weighted to determine the dry mass weight, expressed in grams per plant.

The control data was analyzed regarding its normality using the Shapiro-Wilk test on the raw data. After the F-test variance analysis, a regression analysis was carried out on the significant data, using the SigmaPlot 10.0 software (Sigmaplot, 2007). The data of dry mass weight and the final control rate at 50 DAA, were submitted to the Tukey test ($p \leq 0,05$).

RESULTS AND DISCUSSION

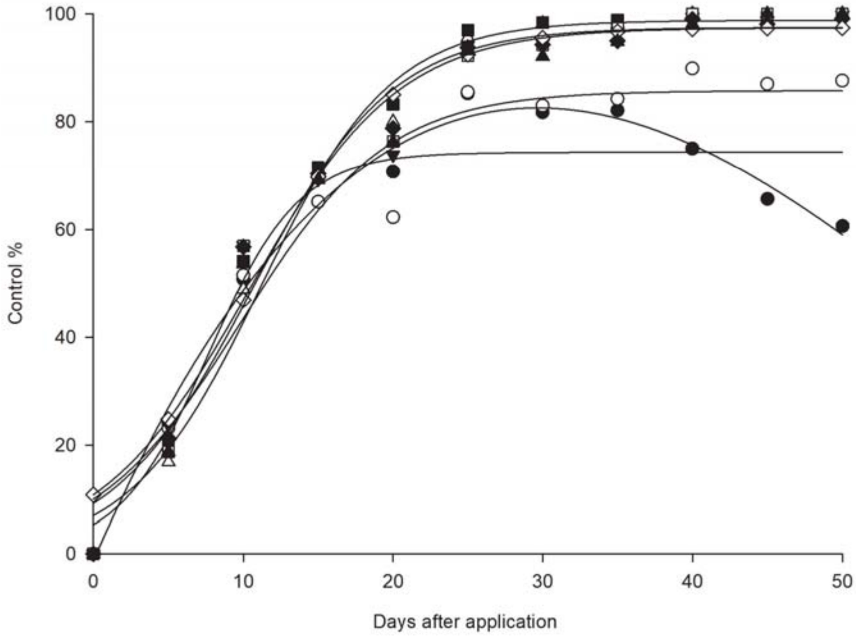
The herbicide treatments tested here were always associated with the glyphosate, as this region has a high sumatran fleabane (*C. sumatrensis*) infestation history that with the application of glyphosate alone, at rates up to 4,800 g e.a. ha^{-1}, being reportedly ineffective. In the Toledo-PR region there are reports of glyphosate and chlorimuron-ethyl resistant *C. sumatrensis* plants (Santos et al., 2014a). According to the normality test, the data presented a normal distribution ($p \leq 0,05$). The variance analysis shows that all interaction between treatments and the sumatran fleabane developments stages were significant (Table 2).

Table 2 - p-values for ANOVA analysis of the treatments and stages evaluated in the sumatran fleabane control experiment, Toledo (PR), 2016

Variation source	n-1	5 DAA	10 DAA	15 DAA	20 DAA	25 DAA	30 DAA
Treatments	9	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Stages	2	< 0.0001	0.0002	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Treatments x stages	18	0.0307	0.0296	0.0003	< 0.0001	< 0.0001	0.0021
VC%	-	23.22	9.54	4.51	4.73	5.41	6.51
Variation source	n-1	35 DAA	40 DAA	45 DAA	50 DAA	Dry wheigt	
Treatments	9	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	
Stages	2	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	
Treatments x stages	18	0.0095	0.0002	0.0018	0.0031	0.0469	
VC%	-	7.40	8.53	12.07	13.48	25.66	

Sumatran fleabane control in stage 1 (8 leaves – 5 to 10 cm)

According to Constantin et al. (2013), the horseweed size at the moment of application has a fundamental influence in the herbicide efficiency. The data of control for stage 1 shows the differences in the speed of control, expressed in the respective treatments equations (Figure 2). For glyphosate + 2,4-D at 1,440 + 806 g e.a. h^{-1}, 80% control was obtained at 25 DAA and the maximum control at 32 DAA; after this point, this treatment showed decrease in control. This is due to the plant's ability to metabolize the herbicide and, consequently, regrowth.



● Glyphosate (1,440 g a.e. ha-1) + 2,4-D (816 g a.e. ha-1); ○ Glyphosate (1,440 g a.e. ha-1) + 2,4-D (943 g a.e. ha-1); ▼ Glyphosate (1,440 g a.e. ha-1) + 2,4-D (1,209 g a.e. ha-1); Δ Glyphosate (1,440 g a.e. ha-1) + [halauxifen-methyl [5.06 g a.i. ha-1] + diclosulam [25.52 g a.i. ha-1]]; ■ Glyphosate (1,440 g a.e. ha-1) + [halauxifen-methyl [6.32 g a.i. ha-1] + diclosulam [31.87 g a.i. ha-1]]; □ Glyphosate (1,440 g a.e. ha-1) + [halauxifen-methyl [5.00 g a.i. ha-1] + 2,4-D [783 g a.e. ha-1]]; ♦ Glyphosate (1,440 g a.e. ha-1) + [halauxifen-methyl [6.00 g a.i. ha-1] + 2,4-D [940 g a.e. ha-1]]; ◇ Glyphosate (1,440 g a.e. ha-1) + [halauxifen-methyl [5.00 g a.i. ha-1]] e ▲ Glyphosate (1,440 g a.e. ha-1) + [halauxifen-methyl [6.00 g a.i. ha-1]].

Figure 2 - Percentage of sumatran fleabane control (stage 1) along the days after the herbicide treatments application. Toledo (PR), 2016.

According to Oliveira Neto et al. (2010a), the percentage to control horseweed around 80% allow the plant regrowth, leading to losses in future crops. Santos et al. (2015) experiment showed that, a 100% control of small sumatran fleabane (5 to 7 cm) was observed with glyphosate + 2,4-D at 900 + 1,042 g e.a. ha^{-1} rate; in the present study, complete control was observed solely in the glyphosate + 2,4-D at 1,440 + 1,209 g e.a. ha^{-1} treatment.

In the treatments glyphosate + 2,4-D at 1,440 + 943 and at 1,440 + 1,209 g e.a. ha^{-1} Figure 2 and Table 3) a relation between the increase rate of 2,4-D and increased control was observed. The glyphosate + 2,4-D at 1,440 + 943 g e.a. ha^{-1} treatment achieved a maximum control of 85% at 33 DAA; after this point, a reduction in control, was observed. On the other hand, the maximum control achieved for the glyphosate + 2,4-D at 1,440 + 1,209 g e.a. ha^{-1} treatment was 97% at 38 DAA, followed by control stabilization.

Table 3 - Equations of percentage of control to sumatran fleabane (stage 1) at 5, 10, 15, 20, 25, 30, 35, 40, 45 and 50 days after treatment application, Toledo (PR), 2016

Treatment	Equation *	R^2
1- Glyphosate + 2,4-D	$Y = -1.239 + 6.322x - 0.140x^2 + 0.0008x^3$	0.99
2 - Glyphosate + 2,4-D	$Y = 2.196 + 5.231x – 0.083x^2$	0.99
3 - Glyphosate + 2,4-D	Y = 97.43/(1+exp(-(x-10.37)/4.99))	0.98
4 - Glyphosate + [halauxifen-methyl + diclosulam]	Y = 98.80/(1+exp(-(x-11.17)/4.35))	0.99
5 - Glyphosate + [halauxifen-methyl + diclosulam]	Y = 98.74/(1+exp(-(x-10.89)/5.66))	0.99
6 - Glyphosate + [halauxifen-methyl + 2,4-D]	Y = 97.48/(1+exp(-(x-10.55)/4.68))	0.98
7 - Glyphosate + [halauxifen-methyl + 2,4-D]	Y = 96.28/(1+exp(-(x-10.05)/4.40))	0.99
8 - Glyphosate + [halauxifen-methyl]	Y = 84.13/(1+exp(-(x-8.76)/3.23))	0.98
9 - Glyphosate + [halauxifen-methyl]	Y = 96.53/(1+exp(-(x-10.67)/4.61))	0.99

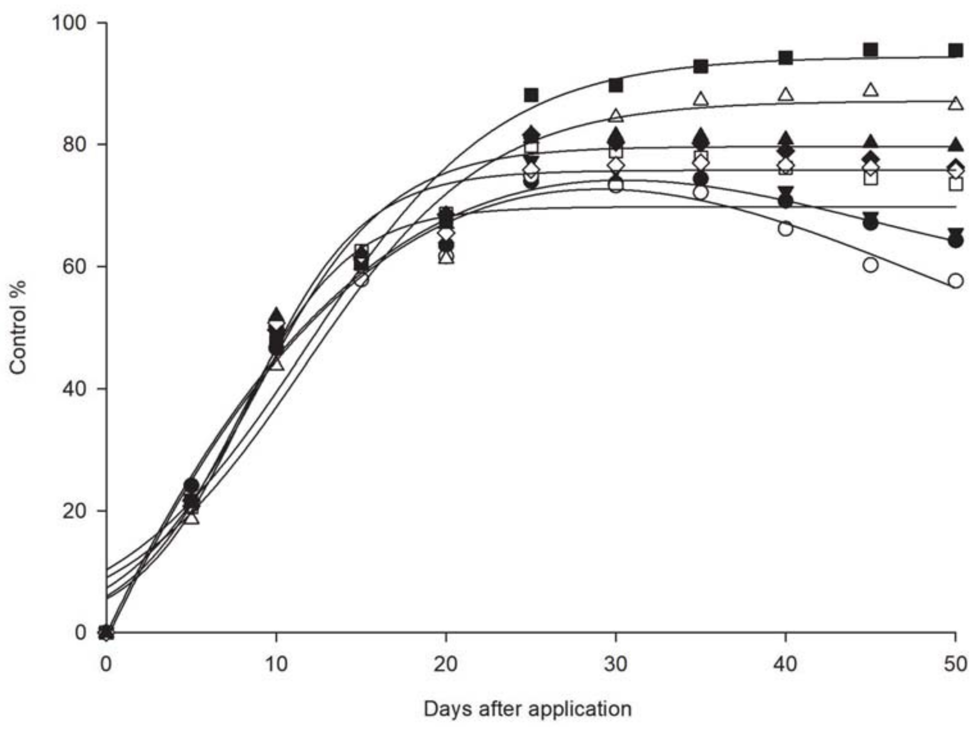
* Significant to a 5% probability.

For the treatments based on halauxifen-methyl + diclosulam, a high control level was observed in both rates: a control above 90% was reached at 25 DAA and at 40 DAA the control was 98% (Table 3). In the treatments of halauxifen-methyl + 2,4-D formulation, there were no observed differences of control between the two rates tested, which the control of sumatran fleabane was 97% at 50 DAA. The application of 5.0 g i.a. ha^{-1} halauxifen-methyl rate resulted in 84% control, but in this treatment there is a risk of regrowth (Oliveira Neto et al., 2010b). However, the treatment containing 6.0 g i.a. ha^{-1} of halauxifen-methyl in the stage 1,the control was completely effective, reaching a 96% average at 50 DAA.

Sumatran fleabane control in stage 2 (19 leaves – 10 to 20 cm)

Sumatran fleabane control evaluations in development stage 2 showed distinct results according the herbicide formulations (Figure 3 and Table 4). A control near 80% was observed only for the glyphosate + 2,4-D at 1,440 + 1,209 g e.a. ha^{-1} treatment. Soares et al. (2012) observed in hairy fleabane when sprayed at 10 to 15 cm using a 2,4-D herbicide 646 g e.a. ha^{-1} ratedosage, while Varga et al. (2007) reported control using a 2,4-D herbicide 1,005 g e.a. ha^{-1} dosage, none of which were observed in this experiment in any 2,4-D dosages associated with glyphosate, showing the advanced development stage tall fleabane tolerance to the herbicide. According to Oliveira Neto (2010b), glyphosate + 2,4-D at 960 + 496 g e.a. ha^{-1} applications in horseweed plants above 14 cm did not provide control above 80%.

Contrary to the control levels observed for stage 1 in sumatran fleabane, here only the halauxifen-methyl + diclosulam treatments achieved a control above 80% among the formulations containing halauxifen-methyl. The glyphosate in association with halauxifen-methyl + diclosulam at 5.06 + 25.52 g i.a. ha^{-1} achieved a maximum control of 86% at 50 DAA. On the other hand, the



● Glyphosate (1,440 g a.e. ha^{-1}) + 2,4-D (816 g a.e. ha^{-1}); ○ Glyphosate (1,440 g a.e. ha^{-1}) + 2,4-D (943 g a.e. ha^{-1}); ▼ Glyphosate (1,440 g a.e. ha^{-1}) + 2,4-D (1,209 g a.e. ha^{-1}); Δ Glyphosate (1,440 g a.e. ha^{-1}) + [halauxifen-methyl [5.06 g a.i. ha^{-1}] + diclosulam [25.52 g a.i. ha^{-1}]]; ■ Glyphosate (1,440 g a.e. ha^{-1}) + [halauxifen-methyl [6.32 g a.i. ha^{-1}] + diclosulam [31.87 g a.i. ha^{-1}]]; □ Glyphosate (1,440 g a.e. ha^{-1}) + [halauxifen-methyl [5.00 g a.i. ha^{-1}] + 2,4-D [783 g a.e. ha^{-1}]]; ♦ Glyphosate (1,440 g a.e. ha^{-1}) + [halauxifen-methyl [6.00 g a.i. ha^{-1}] + 2,4-D [940 g a.e. ha^{-1}]]; ◇ Glyphosate (1,440 g a.e. ha^{-1}) + [halauxifen-methyl [5.00 g a.i. ha^{-1}]] e ▲ Glyphosate (1,440 g a.e. ha^{-1}) + [halauxifen-methyl [6.00 g a.i. ha^{-1}]].

Figure 3 **- Percentage of sumatran** fleabane control (stage 2) along the days after the herbicide treatments application. Toledo (PR), 2016.

Table 4 - Equations of percentage of control to sumatran fleabane (stage 2) at 5, 10, 15, 20, 25, 30, 35, 40, 45 and 50 days after treatment application, Toledo (PR), 2016

Treatment	Equation*	R^2
1- Glyphosate + 2,4-D	Y = 69.82/(1+exp(-(x-7.75)/3.26))	0.98
2 - Glyphosate + 2,4-D	$Y = -1.176 + 5.928x - 0.145x^2 + 0.0010x^3$	0.98
3 - Glyphosate + 2,4-D	Y = 71.25/(1+exp(-(x-7.79)/3.02))	0.98
4 - Glyphosate + [halauxifen-methyl + diclosulam]	Y = 87.19/(1+exp(-(x-11.64)/5.39))	0.99
5 - Glyphosate + [halauxifen-methyl + diclosulam]	Y = 94.46/(1+exp(-(x-10.36)/4.24))	0.99
6 - Glyphosate + [halauxifen-methyl + 2,4-D]	Y = 75.78/(1+exp(-(x-8.42)/3.31))	0.99
7 - Glyphosate + [halauxifen-methyl + 2,4-D]	Y = 78.25/(1+exp(-(x-8.82)/3.72))	0.99
8 - Glyphosate + [halauxifen-methyl]	Y = 75.12/(1+exp(-(x-8.35)/3.41))	0.99
9 - Glyphosate + [halauxifen-methyl]	Y = 79.68/(1+exp(-(x-8.89)/3.87))	0.99

* Significant to a 5% probability.

glyphosate association with halauxifen-methyl + diclosulam at 6.32 + 31.87 g i.a. ha^{-1} showed an 80% control level at 18 DAA and a maximum control of 100% at 50 DAA (Tables 3 and 6). The faster and higher control showed by the halauxifen-methyl + diclosulam may be related to the quick diclosulam absorption. According to Grey and Prostko (2015) and Everman et al. (2006), the diclosulam is absorbed in the leaves and the roots and moves quickly (~48 hours) to the apical growth regions, causing greater control in the target plants (in our case, the sumatran fleabane).

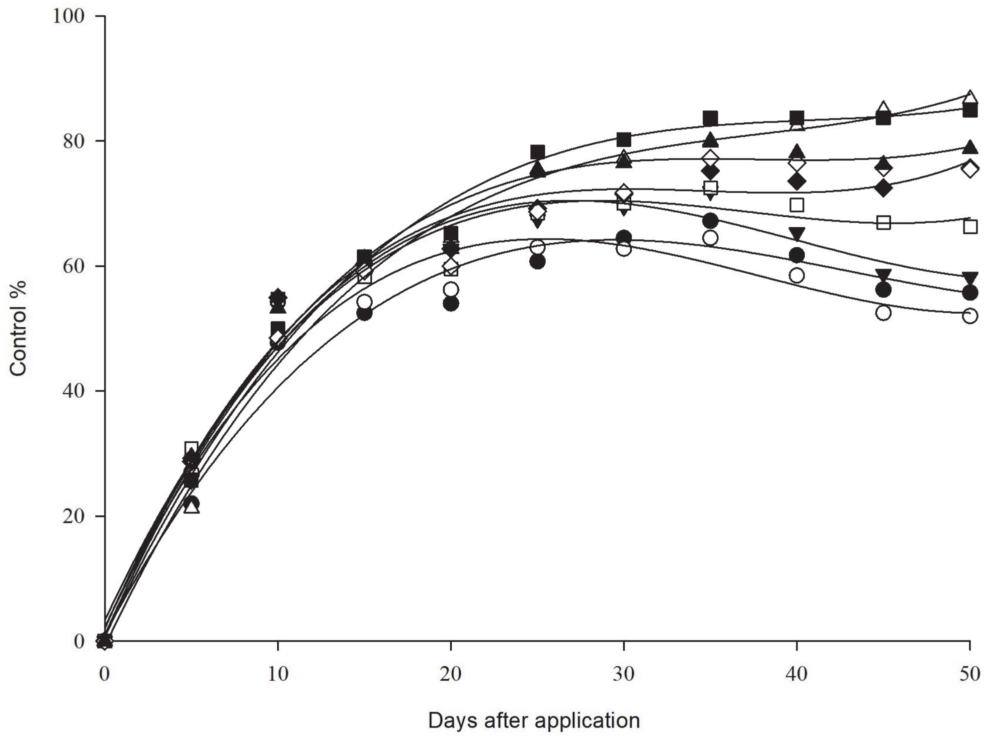
Sumatran fleabane control in stage 3 (45 leaves – 20 to 30 cm)

Treatments containing glyphosate + 2,4-D did not show acceptable control levels, above 90%, for stage 3 (Figure 4, Table 5). The treatment containing 2,4-D rates reached a maximum control level of 66% at 27 DAA, with a control decrease afterwards due to plants regowth. The glyphosate association + 2,4-D at 1,440 + 1,209 g e.a. ha^{-1} achieved a 74% maximum control at 27 DAA. It is known that for the control of advanced stage of sumatran fleabane, with plants above 20 cm, only one application may not be enough. In these cases, a first sequential application of systemic herbicides is recommended, followed by a contact application 7 to 15 days after the first treatment (Constantin et al., 2013).

In the treatment containing halauxifen-methyl + diclosulam, a control above 80% was observed, a level considered acceptable for one application in 20 to 30 cm sumatran fleabane plants. The glyphosate association with halauxifen-methyl + diclosulam (1,440 g e.a. ha^{-1} + [5.06 + 25.52 g i.a. ha^{-1}]) reached an 80% control level at 32 DAA; while the glyphosate association with halauxifen-methyl + diclosulam (1,440 g e.a. ha^{-1} + [6.32 + 31.87 g i.a. ha^{-1}]), already, showed an 80% control level at 27 DAA. The associations containing the new auxin source (halauxifen-methyl) reached control levels below 80% for stage 3 sumatran fleabane. Nevertheless, these levels were higher than the ones found for the 2,4-D associations, which are currently being used for sumatran fleabane weed control.

The final control evaluation (at 50 DAA), presented in Table 6, shows that the plant development stage at the time of application is a fundamental variable for sumatran fleabane control, specially when using glyphosate + 2,4-D associations. For stage 1 plants, the glyphosate + 2,4-D at 1,440 + 943 and 1,440 + 1,209 g e.a. ha^{-1} formulations showed a statistically acceptable control level, above 80%. For stages 2 and 3, however, a satisfactory control level was not observed.

Considering the associations containing halauxifen-methyl, it was found that formulations containing halauxifen-methyl + diclosulam showed 100% control for stage 1 sumatran fleabane, between 85 and 95% for stage 2 plants, and 85% for stage 3 (Table 6). For associations containing halauxifen-methyl + 2,4-D, the results showed that both rates were effective in stage 1 (100% control) and lower than 77% for stages 2 and 3. As for the glyphosate + halauxifen-methyl at 1,440 + 6.32 g ha^{-1} associations, it also showed a higher control level for stage 1 sumatran fleabane in relation to the other two stages evaluated (Table 6).



● Glyphosate (1,440 g a.e. ha-1) + 2,4-D (816 g a.e. ha-1); ○ Glyphosate (1,440 g a.e. ha-1) + 2,4-D (943 g a.e. ha-1); ▼ Glyphosate (1,440 g a.e. ha-1) + 2,4-D (1,209 g a.e. ha-1); Δ Glyphosate (1,440 g a.e. ha-1) + [halauxifen-methyl [5.06 g a.i. ha-1] + diclosulam [25.52 g a.i. ha-1]]; ■ Glyphosate (1,440 g a.e. ha-1) + [halauxifen-methyl [6.32 g a.i. ha-1] + diclosulam [31.87 g a.i. ha-1]]; □ Glyphosate (1,440 g a.e. ha-1) + [halauxifen-methyl [5.00 g a.i. ha-1] + 2,4-D [783 g a.e. ha-1]]; ♦ Glyphosate (1,440 g a.e. ha-1) + [halauxifen-methyl [6.00 g a.i. ha-1] + 2,4-D [940 g a.e. ha-1]]; ◇ Glyphosate (1,440 g a.e. ha-1) + [halauxifen-methyl [5.00 g a.i. ha-1]] e ▲ Glyphosate (1,440 g a.e. ha-1) + [halauxifen-methyl [6.00 g a.i. ha-1]].

Figure 4 - Percentage of sumatran fleabane control (stage 2) along the days after the herbicide treatments application. Toledo (PR), 2016.

Table 5 - Equations of percentage of control to sumatran fleabane (stage 3) at 5, 10, 15, 20, 25, 30, 35, 40, 45 and 50 days after treatment application, Toledo (PR), 2016

Treatment	Equation*	R^2
1- Glyphosate + 2,4-D	$Y = 1.07 + 5.19x - 0.13x^2 + 0.0010x^3$	0.99
2 - Glyphosate + 2,4-D	$Y = 2.19 + 5.88x - 0.17x^2 + 0.0015x^3$	0.97
3 - Glyphosate + 2,4-D	$Y = 0.95 + 6.21x - 0.17x^2 + 0.0015x^3$	0.99
4 - Glyphosate + [halauxifen-methyl + diclosulam]	$Y = 0.62 + 5.84x - 0.14x^2 + 0.0011x^3$	0.99
5 - Glyphosate + [halauxifen-methyl + diclosulam]	$Y = -0.82 + 5.83x - 0.14x^2 + 0.0013x^3$	0.99
6 - Glyphosate + [halauxifen-methyl + 2,4-D]	$Y = 3.28 + 5.91x - 0.17x^2 + 0.0015x^3$	0.98
7 - Glyphosate + [halauxifen-methyl + 2,4-D]	$Y = 2.00 + 6.25x - 0.18x^2 + 0.0018x^3$	0.99
8 - Glyphosate + [halauxifen-methyl]	$Y = 2.83 + 5.48x - 0.14x^2 + 0.0012x^3$	0.99
9 - Glyphosate + [halauxifen-methyl]	$Y = 2.15 + 6.02x - 0.16x^2 + 0.0014x^3$	0.99

* Significant to a 5% probability.

The evaluation of dry mass at 60 DAA (Table 7) including the remaining stage 2 and 3 plants since, as a rule, the stage 1 plants were controlled by the herbicide applications (Figure 2). The results indicate a significant dry mass reduction for the stage 2 when compared to untreated, showing that all management tested were effective to reduce the dry mass at this stage; while for the stage 3, only the glyphosate + [halauxifen-methyl + diclosulam] at 1,440 g e.a. ha^{-1} +[6.32 + 31.87 g i.a. ha^{-1}] showed a dry mass significantly lower than the untreated.

Table 6 **-** Percentage of control to sumatran fleabane at 50 days after treatment application, Toledo (PR), 2016

Treatment	Sumatran fleabane development stage		
	Stage 1	Stage 2	Stage 3
1- Glyphosate + 2,4-D	60.62 Ba	57.62 Da	52.00 Da
2 - Glyphosate + 2,4-D	87.62 Aa	64.25 CDb	55.75 CDb
3 - Glyphosate + 2,4-D	99.75 Aa	65.50 CDb	58.25 CDb
4 - Glyphosate + [halauxifen-methyl + diclosulam]	100.00 Aa	86.50 ABa	85.00 Aa
5 - Glyphosate + [halauxifen-methyl + diclosulam]	99.75 Aa	95.50 Aa	86.75 Aa
6 - Glyphosate + [halauxifen-methyl + 2,4-D]	100.00 Aa	73.50 Bb	66.25 Cb
7 - Glyphosate + [halauxifen-methyl + 2,4-D]	99.12 Aa	76.25 Bb	75.75 Bb
8 - Glyphosate + [halauxifen-methyl]	80.37 ABa	75.75 Ba	75.50 Ba
9 - Glyphosate + [halauxifen-methyl]	100.00 Aa	79.75 Bb	78.75 Bb
10 - Untreated	0.00 Ca	0.00 Ea	0.00 Ea
VC%	13.48		

Equal upper case letters in the column and equal lower case letters in the line do not present significant differences in the Tukey test ($p \leq 0,05$).

Table 7 **-** Dry mass to sumatran fleabane at 60 days after treatment application, Toledo (PR), 2016

Treatment	Sumatran fleabane development stage	
	Stage 2	Stage 3
1- Glyphosate + 2,4-D	12.74 Ba	19.43 ABa
2 - Glyphosate + 2,4-D	12.26 Ba	18.49 ABa
3 - Glyphosate + 2,4-D	12.58 Bb	18.89 ABa
4 - Glyphosate + [halauxifen-methyl + diclosulam]	11.93 Ba	17.36 ABa
5 - Glyphosate + [halauxifen-methyl + diclosulam]	11.76 Ba	14.30 Ba
6 - Glyphosate + [halauxifen-methyl + 2,4-D]	11.99 Ba	16.95 ABa
7 - Glyphosate + [halauxifen-methyl + 2,4-D]	12.37 Ba	15.35 ABa
8 - Glyphosate + [halauxifen-methyl]	11.98 Ba	18.88 ABa
9 - Glyphosate + [halauxifen-methyl]	12.93 Bb	23.63 ABa
10 - Untreated	27.24 Aa	28.28 Aa
VC %	25.66	

Equal upper case letters in the column and equal lower case letters in the line do not present significant differences in the Tukey test ($p \leq 0,05$).

The results of this experiment show that the best period to control sumatran fleabane is at the early development stages. Other authors also have observed that the control levels are higher for younger plants (Vangessel et al., 2009) than on more advanced development stage. According to Santos et al. (2014b), the development stage influences the plant's sensitivity to glyphosate and chlorimuron-ethyl herbicides due to the increase of trichome density and the decrease of the number of stomas. Another possible explanation for lower control of advanced stages in *Conyza* spp. is the lower rate of absorption due to a thicker cuticle, limited translocation and the plants enhanced ability to metabolize the herbicide (Koger and Reddy, 2005); according to Braz et al. (2017), higher development stages demand higher herbicide rates. However, comparing the glyphosate + 2,4-D formulation rates, only the 1,440 + 1,209 g e.a. ha^{-1} rate allowed the control for stage 1; for the other stages, no glyphosate + 2,4-D rates showed acceptable control levels at 50 DAA.

The sumatran fleabane control was easier when carried out at early development stages. Regardless of the plants stage at the moment of application, the better control levels were obtained with associations containing glyphosate + [halauxifen-methyl + diclosulam] at 1,440 g e.a. ha^{-1}+ [6.32 + 31.87 g i.a. ha^{-1}], showing that the halauxifen-methyl combined with diclosulam is an option for this species management in the agricultural systems.

REFERENCES

Bell J.L. et al. Arylex™ mode and site of action characterization. In: Weed Science Society of America and Canadian Weed Science Society/Société Canadienne de Malherbologie; 2014. [acesssed in: March 09. 2017]. Available at http://wssaabstracts.com/public/22/abstract-389.html.

Braz G.B. et al. Sumatran Fleabane (Conyza sumatrensis) control in no-tillage soybean with diclosulam plus halauxifen-methyl. **Weed Technol.** 2017:31:184-92.

Calderón Villalobos L.I. et al. A combinatorial TIR1/AFB-Aux/IAA co-receptor system for differential sensing of auxin. **Nature Chem Biol.** 2012;8:477-85.

Constantin J. Manejo de buva na entressafra. In: Constantin J. et al. **Buva:** fundamentos e recomendações para manejo. Curitiba: Omnipax, 2013. p.41-64.

European Food Safety Authority – EFSA. Conclusion on the peer review of the pesticide risk assessment of the active substance halauxifen-methyl (XDE-729 methyl). 2015. [accessed in: December 06 2016]. Available at: <http://www.efsa.europa.eu/sites/default/files/scientific_output/files/ main_documents/3913.pdf.

Everman W.J. et al. Influence of diclosulam postemergence application timing on weed control and peanut tolerance. **Weed Technol.** 2006;20:651-7.

Grey T.L., Prostko E.P. Uptake, translocation, and dose response of postemergence applied diclosulam to bristly starbur (*Acanthospermum hispidum*). **Peanut Sci.** 2015;42:23-9.

Grossmann K. Auxin herbicides: current status of mechanism and mode of action. **Pest Manage Sci.** 2010;66:113-20.

Instituto Agronômico do Paraná – IAPAR. Cartas Climáticas do Paraná – Precipitação. 2014. [accessed in: November 25 2016]. Available at: http://www.iapar.br/modules/conteudo/conteudo.php?conteudo=595.

Koger C.H., Reddy K.N. Role of absorption and translocation in the mechanism of glyphosate resistance in horseweed (*Conyza canadensis*). **Weed Sci.** 2005;53:84-9.

Lee S. et al. Defining binding efficiency and specificity of auxins for SCFTIR1/AFBAux/IAA co-receptor complex formation. **ACS Chem Biol.** 2014;9:673-82.

Oliveira Neto A.M. et al. Estratégias de manejo de inverno e verão visando ao controle de *Conyza bonariensis* e *Bidens pilosa*. **Planta Daninha**. 2010a;28:1107-16.

Oliveira Neto A.M. et al. Manejo de *Conyza bonariensis* com glyphosate + 2, 4-D e amônio-glufosinate em função do estádio de desenvolvimento. **Rev Bras Herb.** 2010b;9:73-80.

Santos F.M et al. Herbicidas alternativos para o controle de *Conyza sumatrensis* (Retz.) resistentes aos inibidores da ALS e EPSPs. **Rev Ceres**. 2015;62:531-8.

Santos G. et al. Multiple resistance of *Conyza sumatrensis* to Chlorimuron-ethyl and to glyphosate. **Planta Daninha**. 2014a;32:409-16.

Santos F.M. et al. Estádio de desenvolvimento e superfície foliar reduzem a eficiência de chlorimuron-ethyl e glyphosate em *Conyza sumatrensis*. **Planta Daninha**. 2014b;32:361-75.

SigmaPlot. Scientific Graphing Software. Version 10.0. 2007.

Soares D.J. et al. Control of glyphosate resistant hairy fleabane (*Conyza bonariensis*) with dicamba and 2,4-D. **Planta Daninha**. 2012;30:401-6.

Sociedade Brasileira da Ciência das Plantas Daninhas – SBCPD. **Procedimentos para instalação, avaliação e análise de experimentos com herbicidas**. Londrina: 1995. 42p.

Troyer J.R. In the beginning: the multiple discovery of the first hormone herbicides. **Weed Sci.** 2001;49:290-7.

Vangessel M.J. et al. Influence of glyphosate-resistant horseweed (*Conyza canadensis*) growth stage on response to glyphosate applications. **Weed Technol.** 2009;23:49-53.

Vargas L. et al. *Conyza bonariensis* (L.) Cronq biotypes resistant to glyphosate in southern Brazil. **Planta Daninha**. 2007;25:573-8.

Walsh T.A. et al. Mutations in an auxin receptor homolog AFB5 and in SGT1b confer resistance to synthetic picolinate auxins and not to 2,4-dichlorophenoxyacetic acid or indole-3-acetic acid in Arabidopsis. **Plant Physiol.** 2006;142:542-52.

Woodward A.W., Bartel B. Auxin: regulation, action, and interaction. **Ann Bot.** 2005;95:707-35.