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CHEMICAL CONTROL IN PRE-EMERGENCE AND POST-EMERGENCE OF SPERMACOCE VERTICILLATA

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ABSTRACT

The button broom (Spermacoce verticillata) is a weed that has been causing great losses in several producing regions of Brazil. The scarcity of information on the control of this species makes it difficult to manage it. As a result, the present work aimed to identify alternatives for the control of button broom at different stages of development. Three experiments were carried out in a greenhouse in a completely randomized design with four replications. The first experiment was with herbicides in pre-emergence, the second with the application of herbicides in the initial post-emergence when the plants of S. verticillata had four and six fully expanded true leaves, and the third experiment, also with the post-emergence with application in the flowering phase of the plants. For the herbicides applied in pre-emergence and initial post-emergence at 28 DAA, at least one herbicide of the mechanisms of action tested was considered effective in the control of S. verticillata, presenting results above 80%. For the flowering stage, the best control results were obtained with the combination of Glufosinate ammonia and Flumioxazin and Glufosinate ammonium alone in application B, achieving a control efficacy above 90%. However, in some treatments, even after the complete elimination of the leaves, it was observed that the central part of the stem remained green, suggesting slight signs of possible regrowth, resulting only in a temporary interruption in the growth of the plant.

Keywords: Button Broom Control. Phenological Stage. Sequential Application.

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INTRODUCTION

The button broom (*Spermacoce verticillata*) is a highly feared species in the Midwest regions of Brazil and is widespread in crop areas and pastures (Cerqueira, 2009). There are also reports of this species in the northeast region (Silva, 2017) and north of the country (Menezes *et al*., 2018). In recent years, complaints related to control failures with herbicides, especially after the application of glyphosate, have been increasingly frequent, as well as the influence of the plant's developmental stage (Martins; Chritoffoleti, 2014).

Spermacoce verticillata is a herbaceous plant, with a high rate of reproduction through seeds, with a perennial cycle and reproducing both in bright and diffuse places, its root is pivoting and adapts well to soils with low fertility (Moreira & Bragança, 2010). It has the competitive ability to immobilize mineral nutrients in its tissues, making it unavailable for nearby culture (Fontes; Tonato, 2016). The coexistence of six button broom plants per m² throughout the soybean crop cycle can reduce productivity by up to 25% (Lourenço, 2018).

The button broom, in addition to having excellent competitive skills, is a glyphosate-tolerant species (Fadin, 2017). Tolerance is an innate ability of a species to withstand the application of a herbicide at the recommended dose, in which it would have a satisfactory control for other species and can even cause death, however, for tolerant species they do not cause major changes to their development, being a natural characteristic of the species (Christoffoleti, 2016).

This tolerance to glyphosate of this species is due to translocation and absorption, in which in the development phases greater than 4 to 6 leaves there is less translocation of the herbicide to the leaves and roots (Fadin et al., 2018). This tolerance can still be aggravated by having only two registered herbicide options glufosinate and [picloram + 2,4-D] (Adapar, 2023).

The escape from control of this species is mainly related to the plant's developmental stage, in which adult plants have greater difficulty in controlling compared to younger plants (Fadin, 2017).

Due to the intensity of the escape of flowering plants of button broom, the use of only a single application has not reached desired levels of efficiency, which has led to the use of different combinations of herbicides in sequential applications. These sequential applications are intended to increase control levels and diversify the mechanisms of action of herbicides. In view of the reports of increased infestation of this species, the selection of

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herbicides with potential for its control is essential to support management systems. Thus, the objective of this work was to evaluate efficient alternatives of herbicides applied in pre and post-emergence aiming at the control of *Spermacoce verticillata.*

MATERIAL AND METHODS

The experiment was installed and conducted in a greenhouse at the Training and Irrigation Center of the State University of Maringá (UEM), located at latitude of 23º 23'51"S and longitude of 51º56'56" W, at 542 meters of altitude.

Pots of 5 dm3 capacity were used with soil with pH in CaCl2 of 4.9; 4.15 cmolc of H+Al+3 dm-3 of soil; 1.37 cmolc dm-3 of Ca+2; 0.83 cmolc dm-3 of Mg+2; 0.28 cmolc dm-3 of K+; 17 mg dm-3 of P; 20 g dm-3 of C; 69.6% of sand; 6.9% of silt and 23.5% of clay.

EXPERIMENT 1 – HERBICIDES APPLIED IN PRE-EMERGENCE

In each pot, 100 seeds of *S. verticillata* were sown on the soil surface. The herbicides were applied soon after sowing. For the herbicides applied in pre-emergence, 25 treatments were evaluated, whose doses are in parentheses: pendimethalin (800 g ha^{-1}), s-metolachlor (1440 g ha^{-1}), trifluralin (890 g ha^{-1}), pyroxasulfone (100 g ha^{-1}), diclosulam (25.2 g ha^{-1}), chlorimuron-ethyl (15 g ha^{-1}), imazapique (105 g ha^{-1}), trifloxysulfuron sodium (7.50 g ha^{-1}), imazethapyr (106 g ha^{-1}), imazaquin (150 g ha^{-1}), pyrithiobac-sodium (42 g ha^{-1}), [imazapic + imazapyr] (52.5+17.5 g ha^{-1}), [flumioxazin+ imazathapyr] (50 + 106 g ha^{-1}), sulfentrazone (300 g ha^{-1}), flumioxazin (50 g ha^{-1}), fomesafen (375 g ha^{-1}), clomazone (720 g ha^{-1}), isoxaflutole (60 g ha^{-1}), metribuzin (480 g ha^{-1}), ametryn (1500 g ha^{-1}), diuron (1500 g ha^{-1}), amicarbazone (280 g ha^{-1}), atrazine (1500 g ha^{-1}), indaziflam (75 g ha^{-1}) and control without herbicide.

EXPERIMENT 2 – HERBICIDES APPLIED IN THE INITIAL POST-EMERGENCE

In each pot, 10 seeds of *S. verticillata* were sown. After plant emergence, thinning was performed to leave three plants per pot (Table 2). The herbicides were applied when the plants had 4 to 6 fully expanded leaves, which occurred 15 days after sowing. For the experiment, 30 treatments were evaluated with the following doses of each herbicide: fomesafen (250 g ha^{-1}), lactofen (180 g ha^{-1}), saflufenacil (35 g ha^{-1}), flumioxazin (50 g ha^{-1}), flumiclorac-pentyl (60 g ha^{-1}), bentazon (720 g ha^{-1}), atrazine (3250 g ha^{-1}), imazethapyr (106 g ha^{-1}), chlorasulan-methyl (39.98 g ha^{-1}), trifloxysulfuron (7.5 g ha^{-1}), nicosulfuron (60 g ha^{-1}),

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chlorimuron-ethyl (20 g $^{ha-1}$), [imazapique + imazapir] (78.75 + 26.25 g $^{ha-1}$), metsulfurom + glyphosate (7980 + 1110 g $^{ha-1}$), metsulfuron + glyphosate (18000 + 1110 g $^{ha-1}$), glufosinate (600 g $^{ha-1}$), glufosinate + 2.4 d (600 + 670 g $^{ha-1}$), paraquat (400 g $^{ha-1}$), paraquat (600 g $^{ha-1}$), paraquat + 2,4-d (400 + 670 g $^{ha-1}$), paraquat + 2,4-d (600 + 670 g $^{ha-1}$), diquat dibromide (400 g $^{ha-1}$), glyphosate (2220 g $^{ha-1}$), mesotrione (192 g $^{ha-1}$), tembotrione (100,8 g $^{ha-1}$), 2,4-d (670 g $^{ha-1}$), dicamba (720 g $^{ha-1}$), glyphosate + 2,4-d (2220 + 335 g $^{ha-1}$), glyphosate + 2,4-d (2220 + 670 g $^{ha-1}$) and control without herbicide.

EXPERIMENT 3 – HERBICIDES APPLIED IN LATE POST-EMERGENCE

The third was a randomized block design, with 3 replications, where each pot constituted an experimental unit in a 12 x 7 factorial scheme, with twelve treatments of herbicide combinations associated in the first application plot (A), in which 12 treatments were evaluated with the following doses of each herbicide: glyphosate (1080 g $^{ha-1}$), Glyphosate + 2,4-D (1080 + 134 g $^{ha-1}$), Glyphosate + 2,4-D (1080 + 268 g $^{ha-1}$), Glyphosate + 2,4-D (1080 + 536 g $^{ha-1}$), Glyphosate + Chlorimuron (1080 + 12.5 g $^{ha-1}$), Glyphosate + 2,4-D + Chlorimuron (1080 + 134 + 12.5 g $^{ha-1}$), Glyphosate + 2,4-D + Chlorimuron (1080 + 268 + 12.5 g $^{ha-1}$), Glyphosate + 2,4-D + Chlorimuron (1080 + 536 + 12.5 g $^{ha-1}$), glyphosate + 2,4-d + chlorimuron + flumioxazin (1080 + 134 + 12.5 + 25 g $^{ha-1}$), glyphosate + 2,4-d + chlorimuron + flumioxazin (1080 + 268 + 12.5 + 25 g $^{ha-1}$), glyphosate + 2,4-d + chlorimuron + flumioxazin (1080 + 536 + 12.5 + 25 g $^{ha-1}$) and control without application (Table 3).

The applications of plots (B) were carried out ten days after the first one, where there were seven treatments of herbicides alone or associated in the respective doses: Without sequential application, glyphosate (720 g $^{ha-1}$), paraquat (300 g $^{ha-1}$), glyphosate + flumioxazine (720 + 30 g $^{ha-1}$), glyphosate + flumioxazine (432 + 30 g $^{ha-1}$), glufosinate ammonia (500 g $^{ha-1}$) and glufosinate + flumioxazin (500 + 30 g ha^{-1}).

For the experiments with pre-emergence and initial post-emergence application, the percentages of control of *S. verticillata* (visual scale 0 to 100%) were evaluated, where 0% corresponds to no control and 100% to death of all plants compared to the control, evaluating 7, 14, 21 and 28 DAA (Days after application). For the late post-emergence experiment, the evaluation of the percentage of visual control was observed at 7 DAA-(A) (Days after application A) only, and later they were evaluated at 14 and 42 days after application DAA-(B) (Days after application B). In all experiments, the data were submitted

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to analysis of variance by the F test and the means were compared by the Scott-Knott cluster test at the level of 5% of probability.

RESULTS AND DISCUSSION

EXPERIMENT 1 – HERBICIDES APPLIED IN PRE-EMERGENCE

Three groups of herbicides were identified for pre-emergence control (Table 1). The first group of herbicides that promoted higher levels of control (≥ 90%) since the first application were [flumioxazin + imazethapyr], sulfentrazone, flumioxazin, fomesafen, clomazone, atrazine and indaziflam). In the second group at 7 DAA, the control is lower than in the first group, however, the percentage of control is improved throughout the evaluations, being: pedimenthalin, diclosulam, isoxaflutole, metribuzin, ametryn, diuron and amicarbazone.

And in the third group, at the end of the evaluations, no herbicide improved its control above 80% up to 28 DAA, being: s-metolachlor, trifluralin, pyroxasulfone, chlorimuron, imazapique, trifloxysulfuron, imazethapyr, imazaquin, pyrithiobac and [imazapic + imazapyr].

Table 1. Percentage of control (visual evaluation, 0 to 100%) of button broom (*Spermacoce verticillata*) after application of herbicides used in pre-emergence.

Herbicides and doses (g a.i. $^{ha-1}$)		7th DAA		14 DAA		21 DAA		28 DAA	
1	Pedimenthalin (800)	32,50	i	42,50	and	62,50	d	85,50	b
2	Trifluralin (890)	33,75	i	53,75	d	63,75	d	75,00	c
3	S- Metolachlor (1440)	21,25	j	32,50	f	73,00	c	72,50	c
4	Pyroxasulfone (100)	22,50	j	56,25	d	61,25	d	71,25	c
5	Diclosulam (25,2)	65,00	d	82,50	b	82,50	b	84,50	b
6	Chlorimuron – ethyl (15)	61,25	and	75,25	c	78,25	b	78,75	b
7	Trifloxysulfuron sodium (7,50)	51,25	g	60,00	d	68,75	c	75,50	c
8	Imazapic (105)	51,25	g	69,50	c	72,50	c	74,25	c
9	Imazethapyr (106)	50,00	g	58,75	d	62,50	d	72,75	c
10	Imazaquin (150)	15,00	k	18,75	g	15,00	and	12,50	d
11	[Imazapic + Imazapyr] (17,5 + 52,5)	41,25	h	48,47	and	60,00	d	66,75	c
12	Pyrithiobac-sodium (42)	47,50	g	50,00	and	60,00	d	73,75	c
13	[Flumioxazin + imazathapyr] (50 + 106)	100	a	100	a	100	a	100	a
14	Sulfentrazone (300)	100	a	100	a	100	a	100	a
15	Flumioxazin (50)	100	a	100	a	100	a	100	a

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16	Fouzakn (375)	100	a	100	a	100	a	100	a
17	Clomazone (720)	93,00	b	99,00	a	98,50	a	99,75	a
18	Isoxaflutole (60)	77,50	c	88,00	b	98,25	a	99,50	a
19	Metribuzin (480)	61,25	and	99,75	a	99,75	a	100	a
20	Ametryn (1500)	67,00	d	97,50	a	100	a	99,75	a
21	Atrazine (1500)	97,75	a	100	a	99,75	a	100	a
22	Amicarbazone (280)	77,00	c	82,75	b	95,75	a	97,75	a
23	Diuran (1500)	55,00	f	100	a	100	a	100	a
24	Indaziflam (75)	100	a	100	a	100	a	100	a
25	Herbicide-free control	0,00	l	0,00	h	0,00	f	0,00	and
F		**423,08***		**120,48***		**124,25***		**456,85***	
CV (%)		**4,83**		**7,33**		**6,17**		**58,41**	

*Significant at 5% probability by the Scott-Knott test. Averages followed by the same letter and in the same column do not differ from each other.

In a study with weeds of the same family, Gallon (2015) observed that the application of sulfentrazone (600 g $^{ha-1}$), showed control at 7 DAA of (96%) and at 28 DAA (98%), s-metolachlor (1920 g $^{ha-1}$), control at 7 DAA of (42%), however, at this dose at 28 DAA it was sufficient to promote 100% control for *Spermacoce latifolia*, while diclosulam (35 g $^{ha-1}$), chlorimuron (22.5 g $^{ha-1}$) and imazethapyr (100 g $^{ha-1}$) control below (75%) at 28 DAA.

According to Lima (2020), for the species *Spermacoce densiflora* for flumioxazin at 7 DAA there was control of (74%), however, over the course of the evaluations, it reached a control level of (92%) at 28 DAA, while for chlorimuron and s-metolachlor 4% and 10% control at 28 DAA. For the species *Chamaesyce hirta* [flumioxazin + imazethapyr], sulfentrazone, flumioxazin, fomesafen, clomazone, Atrazine, Metribuzin, and Ametryn showed control above 90% (Freitas et al., 2022). These results are indicative of good levels of control of *S. verticillata* in pre-emergence where a herbicide representative with good capacity to promote control is tested in different mechanisms of action.

EXPERIMENT 2 – HERBICIDES APPLIED IN THE INITIAL POST-EMERGENCE

At 28 DAA for the initial post-emergence control with 4 to 6 expanded leaves of *S. verticillata*, the herbicides with excellent control were: lactofen (180), saflufenacil (35), flumioxazin (50), bentazon (720), atrazine (32.50), imazethapyr (106), chlorransulam (39.98), chlorimuron (20), [imazapique + imazapir] (78.75+26.25), metsulfuron + glyphosate (7.98 +1110), metsulfuron + glyphosate (18+1110), glufosinate ammonium (600), glufosinate ammonium + 2,4 D (600+670), paraquat (400), paraquat (600), paraquat

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+ 2,4-D (400+670), paraquat + 2,4-D (600+670), glyphosate (2220), dicamba (720), glyphosate + 2,4-D (2220+335) and glyphosate + 2,4-D (2220+670) and diquat (400).

With control above 80% were the herbicides: fomesafen (250), flumiclorac (60) and mesotrione (192). On the other hand, the herbicides that did not present satisfactory control were: trifloxysulfuron (7.5), nicosulfuron (60), tembotrione (100.8) and 2,4-D (670) (Table 2).

Table 2. Percentage of control of button broom (Spermacoce verticillata) with four to six leaves, after the application of herbicide treatments after post-emergence.

	Herbicides and doses (g a.i. $^{ha-1}$)	7 DAA		14 DAA		21 DAA		28 DAA	
1	Fouzakn (250)	71,25	b	80,75	b	76,25	c	85,00	b
2	Lactophen (180)	87,50	a	97,50	a	100,00	a	100,00	a
3	Saflufenacil (35)	86,25	a	99,50	a	100,00	a	100,00	a
4	Flumioxazin (50)	86,25	a	100,00	a	100,00	a	100,00	a
5	Flumiclorac-pentyl (60)	66,25	b	80,75	b	82	b	88,75	a
6	Bentazon (720)	32,50	and	76,50	b	82,50	b	90,50	a
7	Atrazine (3250)	67,50	b	100,00	a	100,00	a	100,00	a
8	Imazethapyr (106)	26,75	and	59,50	c	77,50	c	91,50	a
9	Cloransulam-methyl (39,98)	25,00	and	82,50	b	100,00	a	100,00	a
10	Trifloxysulfuron sodium (7,5)	23,75	and	79,75	b	73,00	c	78,00	c
11	Nicosulfuron (60)	21,25	and	43,75	d	50,00	d	72,25	c
12	Chlorimuron-ethyl (20)	23,75	and	63,25	c	82,50	b	97,50	a
13	[Imazapique + Imazapir] (78,75+26,25)	23,75	and	75,25	b	83,25	b	97,50	a
14	Metsulfuron$^{/2}$ + Gly$^{/1}$ (7,98 +1110)	37,50	d	85,25	b	99,75	a	100,00	a
15	Metsulfuron$^{/2}$ + Gly$^{/1}$ (18+1110)	45,75	c	79,50	b	99,50	a	100,00	a
16	Glufosinate de amônio (600)	61,25	b	99,50	a	99,75	a	100,00	a
17	Glufosinate + 2.4 D (600+670)	66,25	b	99,00	a	98,75	a	95,50	a
18	Paraquat (400)	89,50	a	99,75	a	99,75	a	99,75	a
19	Paraquat (600)	92,00	a	100,00	a	100,00	a	100,00	a
20	Paraquat + 2,4- D (400+670)	88,00	a	99,50	a	99,50	a	99,50	a
21	Paraquat + 2,4- D (600+670)	84,50	a	98,50	a	99,50	a	99,50	a
22	Diquate (400)	91,25	a	98,25	a	94,50	a	96,25	a
23	Glyphosate (2220)	26,25	and	87,00	b	93,25	a	98,75	a
24	Mesotrione (192)	23,75	and	77,75	b	71,25	c	84,50	b
25	Tembotrione (100.8)	24,25	and	53,75	c	30,00	and	21,75	d
26	2,4-D (670)	40,00	d	40,75	d	53,75	d	73,75	c
27	Dicamba (720)	42,50	d	73,75	b	73,75	c	96,25	a
28	Gly + 2,4-D (2220+335)	49,50	c	88,00	b	97	a	98,50	a
29	Gly + 2,4-D (2220+670)	53,75	c	80,25	b	88,75	a	96,25	a
30	Herbicide-free control	0,00	f	0,00	and	0,00	f	0,00	and
F		**101,70***		**53,25***		**51,12***		**54,81***	
CV (%)		**10,55**		**7,78**		**7,90**		**6,64**	

*Significant at 5% probability by the Scott-Knott test. Averages followed by the same letter and in the same column do not differ from each other. $^{/}$ 1-Glyphosate, $^{/2\text{-Metsulfuron-methyl}}$.

Fadin (2017) found that at 28 DAA the herbicides paraquat, flumioxazin, saflufenacil and chloransulam were effective in controlling *S. verticillata*. While glyphosate (1440 and 2400 g a.e. ha-1), 2,4-D (670 and 1000 g a.e. ha-1), chlorimuron did not show effective

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control at the development stage 4 to 6 expanded leaves, as well as association of glyphosate + 2,4-D at the dose of (1,440 + 670 g $^{ha-1}$ a.e.).

Martins; Chirtoffoleti (2014), for the species *Spermacoce densiflora* with 3 expanded leaves for the herbicides fomesafen, lactofen, paraquat, glyphosate + 2,4-D, chlorimuron, imazethapyr and glyphosate showed excellent control at 21DAA. While Lima et al. (2019), for *Spermacoce densiflora* with 4 leaves and 8 leaves at 21 DAA, the herbicides glufosinate ammonium and flumioxazin showed excellent control, however glyphosate, 2,4-D, glyphosate + 2,4-D and Saflufenacil did not show good control. (Takano et al., 2011) For the species of *S. latifolia* and *R. brasiliensis* with 2 to 4 leaves for glufosinate ammonium and glyphosate showed effective control. Like Ramires (2009), for the species *S. latifólia* with 4 to 6 leaves, the herbicide glyphosate had control above 99% at 35 DAA.

We can analyze that it is necessary to analyze the doses used in glyphosate alone and the mixtures of glyphosate + 2,4-D, as well as the stage of development, it is noted that there may be an influence on the control levels of *S. verticillata*.

EXPERIMENT 3 – HERBICIDES APPLIED IN LATE POST-EMERGENCE

The results of the first evaluation of the control of *S. verticillata* in full bloom under greenhouse conditions at 7 DAA-A (days after application A), it was observed that all the treatments that were performed were not efficient, provided control ≤ 24.23% (Table 3). This can be justified by the fact that the symptoms of the herbicide glyphosate only begin to manifest between the seventh and tenth day after application (ADAPAR, 2023).

Table 3. Percentages of control of flowered button broom (*Spermacoce verticillata*) after a sequential application in an evaluation carried out at 7 DAA (A).

	Herbicides and doses (g a.i. or a.e. $^{ha-1}$)	**(b)$^{/3 \text{ of } 7}$**	
1.	Glyphosate (1080)	4,23	f
2.	Glyphosate + 2,4-D (1080 + 134)	10,33	and
3.	Glyphosate + 2,4-D (1080 + 268)	11,42	d
4.	Glyphosate + 2,4-D (1080 + 536)	12,28	d
5.	Glyphosate + Chlor $^{/1}$(1080 + 12,5)	12,80	d
6.	Glyphosate + 2,4-D + Chlor$^{/1}$ (1080 + 134 + 12,5)	15,38	c
7.	Glyphosate + 2,4-D + Chlor$^{/1}$ (1080 + 268 + 12,5)	15,38	c
8.	Glyphosate + 2,4-D + Chlor $^{/1}$ (1080 + 536 + 12,5)	13,95	c
9.	Glyphosate + 2,4-D + Chlor$^{/1}$ + Flum$^{/2}$ (1080 + 134 + 12,5 + 25)	19,33	b
10.	Glyphosate + 2,4-D + Chlor$^{/1}$ + Flum$^{/2}$ (1080 + 268 + 12,5 + 25)	24,23	a
11.	Glyphosate + 2,4-D + Chlor $^{/1+ \text{Flum}/2}$ (1080 + 536 + 12,5 + 25)	19,85	b
12.	Witness	9,19	and
F		**78,48***	
CV (%)		**19,70**	

/1Chlorimuron- ethyl; /2 Flumioxazin; /3DAA(A) days after application A *Significant at 5% probability by the Scott-Knott test. Averages followed by the same letter and in the same column do not differ from each other.

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The results obtained for the control of button broom at 14 DAA (B) are presented in Table 4. All treatments with glufosinate ammonia plus the addition of flumioxazin in plot (B) showed the highest levels of control with ≥ 80%, except treatment twelve (T12) (without herbicide application in application A) did not have control higher than 80%. For treatments with glufosinate ammonium alone in plot (B), control was verified only in treatment 1 (T1) with control of 81.66%, in treatment five (T5) control of 80% and in treatment eleven (T11) control of 81%. In application B Without sequential, glyphosate, Paraquat, glyphosate plus addition of flumioxazin in the two doses did not present controls ≤ 79.33%.

Table 4. Percentage of control of bud broom (*Spermacoce verticillata*) flowered after the two sequential applications in evaluation carried out at 14 DAA (B).

Herbicides applied on plot A (g a.i. or a.e. $^{ha-1}$)	**Herbicides applied in plot B**						
Plot A	**SS**$^{/4}$	**Gly**$^{/1}$	**Paraq**	**Gly1+F**$^{/3}$	**Gly1*+F**$^{/3}$	**Gluf**$^{/5}$	**Gluf**$^{/5+F/3}$
1.Gly1 (1080)	6,0Cd	26,6Bc	34,0Cb	41,6Bb	26,6Dc	81,6Aa	81,6Aa
2.Gly1 + 2,4-D (1080 + 134)	2,6Dd	10.6Cc	15,0Ec	22,3Cb	18,0Eb	75,0Aa	81,6Aa
3.Gly1 + 2,4-D (1080 + 268)	5.66Ce	14,0Cd	46,6Bb	33.3Cc	28,3Dc	71,0Aa	80,0Aa
4.Gly1 + 2,4-D (1080 + 536)	5,00Cd	13.3Cc	24,0Db	30,0Cb	31,0Db	78,3Aa	89,3Aa
5.Gly1 + Chlor$^{/2}$ (1080 + 12,5)	6,66Bd	17.3Cc	14,3Ec	26,6Cb	29,3Db	80,0Aa	81,6Aa
6.Gly1 + 2,4-D + Chlor$^{/2}$ (1080+134+12,5)	14,0Bc	18.6Cc	16,0Ec	30,0Cb	38,3Cb	75,0Aa	83,3Aa
7.Gly1 + 2,4-D + Chlor$^{/2}$ (1080+268+12,5)	6,6Cd	16,0Cc	18,0Ec	34,0Cb	37,6Cb	77,6Aa	83,3Aa
8.Gly1 + 2,4-D + Chlor$^{/2}$ (1080+536+12,5)	21.6Ac	23,3Bc	41,6Cb	46,6Bb	50,0Bb	66.0From	83,3Aa
9.Gly1 + 2,4-D + Chlor$^{/2}$ + Flu$^{/3}$(1080+134+12,5+25)	12,3Bc	20,0Cb	25,0Db	53,3Bb	69,3Aa	76,6Aa	80,0Aa
10.Gly1 + 2,4-D + Chlor$^{/2+Flu/3}$(1080+268+12,5+25)	23,3Ad	33.3Ac	32.3Cc	53,0Bb	75,0Aa	77,6Aa	80,0Aa
11.Gly1 +2,4-D+ Chlor$^{/2}$ + Flu$^{/3}$(1080+536+12,5+25)	26.6Ac	35.0Ac	32.3Cc	79,3Aa	79,3Aa	81,0Aa	85,0Aa
12. Witnesses	0,0Ee	14,3Cd	57.3From	29.3Cc	35.6Cc	74,3Aa	79,3Aa
F							**6,83***
CV (%)							**7,89**

[1] Glyphosate (1080 g a.e. $^{ha-1}$); glyphosate$^{/1}$ (720 g a.e. $^{ha-1}$); glyphosate $^{/1*}$ (432 g a.e. $^{ha-1}$); $^{/2}$ Chlorimuron-ethyl; $^{/3}$Flumioxazin; $^{/4}$ No sequential; $^{/5}$Glufosinate ammonia. (satisfactory): control of ≥ 80.0 to 100%; (unsatisfactory): control of ≥ 60.0 to 79.99%; (insufficient): control < 60.0%; *Significant at 5% probability by the Scott-Knott test. Averages followed by the same letter do not differ from each other. Uppercase in the column and lowercase in the row.

42 DAA (B) the treatments with glufosinate ammonium plus the addition of flumioxazin all showed 99% ≥ control independent of the treatment in application A. Despite this, it was observed that in some treatments, even with the total fall of the old leaves, the central part of the stem was still greenish with slight signs of possible regrowth, These signs have been noted in all treatments with glufosinate + flumioxazin. Andrade Jr. (2020), when studying the control of *S. verticillata* with the use of the association of

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glufosinate ammonium + flumioxazin, found an increase in control at 14 DAA from 83.8% to 87.55% at 21 DAA, however, when evaluating 28 DAA and 35 DAA, he showed a drop in control to 78.75% and the presence of regrowth in the plants.

Application B with glufosinate alone all treatments were efficient (≥ 94.33 %) regardless of herbicide mixtures or isolated application. However, for these treatments, the presence and beginning of regrowth has already been verified, even with the increase in control in this period of desiccation and fall of old leaves.

In the application of glyphosate (432) plus the addition of flumioxazin (30), the treatments with glyphosate (1080) associated with 2,4-d at the dose of (134) or (268) did not show satisfactory control (56.66% and 78.33%), as well as the isolated application of glyphosate + flumioxazin (72.66%). However, the other treatments showed control above 80% control. For the other treatments in application B for glyphosate (720) plus addition of flumioxazin (30), only glyphosate (1080) + 2,4-d (134) and glyphosate (1080) + 2,4-d (134) + chlorimuron (12.5) + flumioxazin (25) showed low levels of control, however the other treatments showed control above 80%.

Table 5. Percentage of control of bud broom (*Spermacoce verticillata*) flowered after the two sequential applications in evaluation carried out at 42 DAA (B).

Herbicides applied on plot A (g a.i. or a.e. $^{ha-1}$)	**Herbicides applied in plot B**						
Plot A	**SS**$^{/4}$	**Gly**$^{/1}$	**Paraq**	**Gly1+F**$^{/3}$	**Gly1*+F**$^{/3}$	**Gluf**$^{/5}$	**Gluf**$^{/5+F/3}$
1.Gly1 (1080)	14.3Cc	73.3From	72.0From	98,3Aa	88,3Aa	100 Aa	100 Aa
2.Gly1 + 2,4-D (1080 + 134)	3,3Dc	52,3Bb	36,6Cb	78,6Aa	56,6Cb	96,6Aa	100 Aa
3.Gly1 + 2,4-D (1080 + 268)	4,0Dd	51,6Bc	72.6From	80.0From	78,3Bb	98,3Aa	100 Aa
4.Gly1 + 2,4-D (1080 + 536)	4,6Dc	60,0Bb	79,3Aa	92,0Aa	93,3Aa	98,3Aa	100 Aa
5.Gly1 + Chlor$^{/2}$ (1080 + 12,5)	10,0Cc	78.3From	61.6From	70.0From	89,3Aa	98,0Aa	100 Aa
6.Gly1 + 2,4-D + Chlor$^{/2}$ (1080+134+12,5)	15,6Cd	56,6Bb	38.3Cc	91,0Aa	89,6Aa	99,3Aa	100 Aa
7.Gly1 + 2,4-D + Chlor$^{/2}$ (1080+268+12,5)	10,0Cc	73.6From	56,6Bb	86,0Aa	95,0Aa	97,6Aa	100 Aa
8.Gly1 + 2,4-D + Chlor$^{/2}$ (1080+536+12,5)	33,3Bc	66.6From	75.0From	80.0From	80,0Bb	97,3Aa	99,0Aa
9.Gly1 + 2,4-D + Chlor$^{/2}$ + Flu$^{/3}$(1080+134+12,5+25)	10.6Cc	52,3Bb	56,6Bb	78,3Aa	95,6Aa	98,0Aa	99,6Aa
10.Gly1 + 2,4-D + Chlor$^{/2+Flu/3}$(1080+268+12,5+25)	52.6From	78,3Aa	82,3Aa	94,3Aa	98,3Aa	99,0Aa	99,6Aa
11.Gly1 +2,4-D+ Chlor$^{/2}$ + Flu$^{/3}$(1080+536+12,5+25)	51.6From	76,0Aa	91,0Aa	94,6Aa	100 Aa	94,3Aa	100 Aa
12. Witnesses	0.0Ed	25.6Cc	75.3From	82.3From	72,6Bb	95,3Aa	100 Aa
F							**2,73***
CV (%)							**8,49**

[1] Glyphosate (1080 g a.e. $^{ha-1}$); glyphosate$^{/1}$ (720 g a.e. $^{ha-1}$); glyphosate $^{/1*}$ (432 g a.e. $^{ha-1}$); $^{/2}$ Chlorimuron-ethyl; $^{/3}$Flumioxazin; $^{/4}$ No sequential; $^{/5}$Glufosinate ammonia. (satisfactory): control of ≥ 80.0 to 100%; (unsatisfactory): control of ≥ 60.0 to 79.99%; (insufficient): control < 60.0%; *Significant at 5% probability by the Scott-Knott test. Averages followed by the same letter do not differ from each other. Uppercase in the column and lowercase in the row.

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According to Monquero *et al*. (2001), the mixing of glyphosate with flumioxazin resulted in an additive interaction, where the translocation and absorption of Glyphosate was not affected, and provided an effective control for the species *Amaranthus hybridus*, *Commelina benghalensis*, *Richardia brasiliensis* and *Ipomoea grandifolia*.

There is still no recommendation for a package insert of Flumioxazin + Glyphosate or Glufosinate ammonium + flumioxazin for *S. verticillata* and other broadleaf species, however the best results for control have the presence of flumioxazin alone or associated, similar results can be seen in the work of Andrade Jr. (2020), as well as Lima (2020) and Oliveira Neto (2011).

Lima (2020) evaluated the species *Spermacoce densiflora* at 28 DAA in the association of glyphosate (1440) + 2,4-D (1000) in which it presented 72% control even though it was in a lower stage of development. For the association of glyphosate (1440) + chlorimuron (20), it presented a control of 49%. However, for the combination of glyphosate (1440) + Flumioxazin there was 100% control. The results coincide with this study, which in the flowering stage of *S. verticillata* was found to be a much lower control result both in the association of Glyphosate + 2,4-D and in the association of Glyphosate + Chlorimuron.

One of the factors that most influence the control of button broom is its development stage, even if the control levels are high and there is desiccation and the fall of all old leaves, in applications at the flowering stage there is a high incidence of regrowth. According to Romam *et al*., (2005) perennial plants in the flowering development stage consists of the period of lowest percentage of herbicide control, because they will be accumulated in the inflorescences. According to Fadin *et al*. (2018), the species *S. verticillata at the* flowering stage found a greater translocation in a shorter period, in addition to a difference between absorbed and transglued glyphosate, in which at this stage of development (0%) it was found in the leaves and a lower translocation of the herbicide Glyphosate to the root (1%).

For isolated application of Paraquat in application B, only the treatments of glyphosate (1080) + 2,4-d (268) + chlorimuron (12.5) + flumioxazin (25) and glyphosate (1080) + 2,4-d (536) + chlorimuron (12.5) + flumioxazin (25) had good control levels with 82.33 % and 91 %, all others had unsatisfactory control.

For glyphosate alone and non-sequential application, all treatments showed control below 80%. For the treatments evaluated, which consisted of: without sequential,

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glyphosate alone, paraquat, glyphosate + flumioxazin in the two dosages of plot (B), even those with control above 80%, the presence of button broom regrowth occurred.

Regarding the control of the button broom, the treatments of application B that used the mixture of glufosinate + flumioxazin obtained the best results, following an ascending order. Secondly, treatments with glufosinate alone also showed good control. For the combinations of glyphosate (720 g a.e. $^{ha-1}$) + flumioxazin and glyphosate (432 g a.e. $^{ha-1)}$ + flumioxazin, similar control was observed, with most treatments achieving more than 80% efficacy. However, for Paraquat, only the treatments of application A with the presence of Glyphosate + 2,4-D + Chlorimuron + Flumioxazin achieved a control above 80%. Finally, in application B, the treatments with Glyphosate alone and without sequential did not show good control.

FINAL CONSIDERATIONS

We can conclude that for the control of *Spermacoce verticillata* the stages of development are essential for good levels of control, because in the initial stages both in pre-emergence and initial post-emergence different mechanisms of action and herbicides were found. However, for the flowering stage, the management with herbicide mixture and sequential the best control results were for glufosinate ammonium in mixture with flumioxazin and glufosinate ammonium alone in application B, with good efficacy with control above 90%, however, it is observed in some treatments, despite the complete elimination of the leaves, the central portion of the stem remained green, exhibiting subtle indications of possible regrowth with this, only stopping the growth of the plant for a short period of time.

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