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HERBICIDE EFFICACY IN THE FALL MANAGEMENT OF *Richardia brasiliensis*, *Commelina benghalensis*, *Conyza sumatrensis* AND *Digitaria insularis*

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Abstract

Other herbicides, alone or in combination with glyphosate, may be effective in controlling *Richardia brasiliensis, Commelina benghalensis, Conyza sumatrensis* e *Digitaria insularis*. Therefore, the aim of this study was to evaluate the efficacy of herbicides, alone or in combination, in the control of these weeds in the off-season. Three composite experiments were conducted by applying herbicides, alone or in combinations. Experiments 1 and 2 were conducted in Palotina, State of Paraná (PR), Brazil. Experiment 3 in Iporã, PR, Brazil. The three during fall 2017 in fallow areas after soybean harvest. The experiment was a randomized complete block design with 4 replications and weed control at 7, 14, 21, 28, 35, and 42 days after application (DAA). The control of *R. brasiliensis* and *C. benghalensis* was evaluated in the three experiments, the control of *C. sumatrensis*, in experiments 1 and 2, while the control of *D. insularis* was evaluated only in experiment 3. Data were subjected to analysis of variance and F-test ($p < 0.05$). The treatment means values of experiments 1 and 2 were compared by Tukey's test ($p < 0.05$), and the treatment mean values of experiment 3 were grouped by the Scott and Knott test ($p < 0.05$). Some herbicide combinations were effective in controlling *R. brasiliensis*, *C. benghalensis*, in a single or sequential application. Herbicide combinations were effective in controlling *C. sumatrensis* with sequential application. Herbicide combinations in a single application did not provide satisfactory final control (≥ 80%) for *D. insularis*.

Keywords: Chemical Control. Glyphosate. Resistance. Tolerance. Weeds.

1. Introduction

Hairy fleabane (*Conyza bonariensis*), horseweed (*Conyza canadensis*), and Sumatran fleabane (*Conyza sumatrensis*) are among the main weeds found worldwide. *Conyza* spp. has annual life cycle and herbaceous size (Lorenzi 2014) and with high seed production, found in various agricultural environments, such as grain crops (Moreira and Bragança 2011). *C. sumatrensis* has its origin in the subtropical climate region of South America, with dispersal also to Europe, America, and Asia (Hao et al. 2009). Brazil pusley (*Richardia brasiliensis*) is an annual, herbaceous, prostrate plant (Lorenzi 2014), benefited from high light environments found in various agricultural environments such as soybean crops (Moreira and Bragança

2011; Diesel et al. 2018). Another important weed in different environments is Benghal dayflower (*Commelina benghalensis*), which is a very branched evergreen that reproduces by seeds and vegetative structures (Moreira and Bragança 2011; Lorenzi 2014).

In turn, sourgrass (*Digitaria insularis*) is a species native to tropical and subtropical regions of America (Veldman and Putz 2011), found in pastures, coffee plantations, orchards, crops, roadside, and wastelands. It can form rhizomes, clumps, and disseminate propagules (seeds and rhizomes) practically throughout the summer. These characteristics make it very aggressive in competition with cultivated plants (Moreira and Bragança 2011; Lorenzi 2014). All these weeds are important in soybean and maize crops, with control hampered by one of these factors: increased production of propagules, wind dispersal of propagules, resistance or tolerance to herbicides such as glyphosate. For example, a single plant of *Conyza* spp. can produce up to 200,000 seeds in one year (Dauer et al. 2007).

In Brazil, there are cases of *C. sumatrensis* with multiple resistance to chlorimuron and glyphosate (Santos et al. 2014), simple resistance to paraquat (Zobiole et al. 2019), and cases of simple and multiple resistance to these and other herbicides (photosystem II inhibitors, Protox inhibitors, and synthetic auxins) (Heap 2021). *D. insularis* also presents cases of resistance to herbicides in Brazil. With resistance to glyphosate and ACCase inhibitors (fenoxaprop and haloxyfop) (Heap 2021). *R. brasiliensis* and *C. benghalensis* are species with recognized tolerance to some herbicides, such as glyphosate. Besides this scenario of difficulties in the control and cases of resistance/tolerance, studies show the high interference of these species in crops such as soybean and maize. Only 2.7 plants of *C. bonariensis* m^{-2} can already reduce soybean yield by 50% (Trezzi et al. 2015). While 6 plants of *D. insularis* m^{-2} can reduce soybean yield by almost 40% (Gazziero et al. 2019).

Among the factors that lead to the selection of herbicide-resistant weed biotypes is the use of the same herbicides, the strong selection pressure leads to selection of resistant biotypes. Thus, the use of herbicides with different mechanisms of action, herbicide combinations, and the adoption of tools other than chemical control are fundamental in preventing the selection of resistant weed biotypes as well as in their management (Heap and Duke 2018; Kniss 2018).

Thus, other herbicides, alone or in combination with glyphosate, may be effective in controlling *C. sumatrensis*, *D. insularis*, *C. benghalensis,* and *R. brasiliensis*. Therefore, the purpose of this study was to evaluate the efficacy of herbicides, alone and in combination, in the control of these weeds in the off-season.

2. Material and Methods

Three experiments were conducted in the fall of 2017, the areas were fallow with previously grown soybeans. Table 1 presents information on the locations of the experiments. A randomized block design with four replications was used in the three experiments. The treatments consisted of the application of herbicides, alone or in combination, listed in Table 2. For all applications, a CO_2 pressurized backpack sprayer was equipped with six AIXR 110.015 tips, at a pressure of 2.5 kgf cm^{-2} and a speed of 3.6 km h^{-1}, providing an application volume of 150 L ha^{-1}.

Sites of experiments 1 and 2 were infested with *R. brasiliensis*, *C. benghalensis* and *C. sumatrensis*, in the proportion of 30, 27, and 43%, respectively. The site of experiment 3 was infested with *R. brasiliensis*, *C. benghalensis,* and *D. insularis*, in the proportion of 8, 6, and 86%, respectively.

Table 1. Local description of experiments. State of Paraná (PR), Brazil, 2017.

	Local	Geographical coordinates
Exp. 1	Palotina	24°11'45.08"S 53°48'29.30"W
Exp. 2	Palotina	24°11'45.08"S 53°48'29.30"W
Exp. 3	Iporã	24°00'41.82"S 53°38'55.11"W

Table 2. Post-emergence herbicide treatments for the weed control. PR, Brazil, 2017.

	Treatments	Rates[1]
Exp. 1	1. control (without application)	-
	2. (saflufenacil + imazethapyr) + glyphosate*	(35.6+100.4) + 1,440
	3. saflufenacil + glyphosate*	35 + 1,440
	4. flumioxazin + glyphosate	25 + 1,440
	5. diclosulam + glyphosate	35 + 1,440
	6. glyphosate	1.440
	7. (saflufenacil + imazethapyr)*	(35.6+100.4)
	8. saflufenacil*	35
	9. (imazapyr + imazapic)**	(17.5+52.5)
	10. (imazapyr + imazapic) + dicamba**	(17.5+52.5) + 432
Exp. 2	1. control (without application)	-
	2. (saflufenacil + imazethapyr) + glyphosate + dicamba*	(35.6+100.4) + 1440 + 432
	seq. saflufenacil + glyphosate*	*seq.* 70 + 1,440
	3. saflufenacil + glyphosate + dicamba*	35 + 1,440 + 432
	seq. (saflufenacil + imazethapyr)*	*seq.* (35.6+100.4)
	4. saflufenacil + glyphosate + dicamba*	35 + 1,440 + 432
	seq. imazethapyr*	*seq.* 432
	5. saflufenacil + glyphosate + clethodim*	35 + 1,440 + 192
	seq. (paraquat + diuron)**	*seq.* (400+200)
	6. glyphosate + dicamba	1440 + 432
	seq. (paraquat + diuron)**	*seq.* (400+200)
Exp. 3	1. control (without application)	-
	2. (saflufenacil + imazethapyr)*	(17.8+50.2)
	3. (saflufenacil + imazethapyr)*	(26.7+75.3)
	4. (saflufenacil + imazethapyr)*	(35.6+100.4)
	5. (saflufenacil + imazethapyr)*	(44.5+125.5)
	6. dicamba	144
	7. dicamba	288
	8. dicamba	432
	9. dicamba	576
	10. glyphosate	1,440
	11. glyphosate + dicamba	1,440 + 288
	12. glyphosate + (saflufenacil + imazethapyr)*	1,440 + (26.7+75.3)
	13. dicamba + (saflufenacil + imazethapyr)*	288 + (26.7+75.3)
	14. glyphosate + (saflufenacil + imazethapyr) + dicamba*	1,440 + (26.7+75.3) + 288

[1]Rates at g of acid equivalent (ae) ha^{-1}, for glyphosate, imazethapyr, and dicamba. For the others, rates at g of active ingredient (ai) ha^{-1}. *Seq.*: sequential application, 7 days after the first application. *Addition of adjuvant to 0.5% v/v. **Addition of adhesive spreader to 0.5% v/v.

Weed control was evaluated at 7, 14, 21, 28, 35, and 42 days after application (DAA) for the three experiments. Visual analysis was performed in each experimental unit (0 for no damage, up to 100% for plant death), considering, in this case, significantly visible symptoms in the plants, according to their development (Velini et al. 1995).

Data were subjected to analysis of variance by F-test ($p < 0.05$). The treatment means values of experiments 1 and 2 were compared by Tukey's (1949) test ($p < 0.05$), and the treatment mean values of experiment 3 were grouped by the Scott and Knott's (1974) test ($p < 0.05$) (Pimentel-Gomes and Garcia 2002), with the aid of the software Sisvar® 5.3 (Ferreira 2011).

3. Results

Table 3 lists the results of the three experiments for the control of *R. brasiliensis*. For experiment 1, better control percentages at 42 DAA (≥ 92.3%) were observed for application of glyphosate (1,440 g ae ha^{-1}) alone or in combination with saflufenacil + imazethapyr (35.6+100.4 g ai ha^{-1}), diclosulam (35 g ai ha^{-1}), saflufenacil (35 g ai ha^{-1}) or flumioxazin (25 g ai ha^{-1}).

Table 3. *R. brasiliensis* control (%) at 7, 14, 21, 28, 35, and 42 days after application (DAA) of herbicides. PR, Brazil, 2017.

	Treatments	Control at DAA					
		7	14	21	28	35	42
Exp. 1	1. control (without application)	0.0^{b}	0.0^{d}	0.0^{d}	0.0^{c}	0.0^{c}	0.0^{c}
	2. (saflufenacil + imazethapyr) + gly	22.5^{a}	91.3^{a}	95.0^{a}	98.5^{a}	98.8^{a}	99.0^{a}
	3. saflufenacil + gly	17.0^{a}	93.3^{a}	95.8^{a}	98.5^{a}	98.8^{a}	98.8^{a}
	4. flumioxazin + gly	19.3^{a}	90.8^{a}	93.8^{a}	97.8^{a}	98.5^{a}	98.8^{a}
	5. diclosulam + gly	4.5^{b}	54.5^{b}	70.0^{b}	97.3^{a}	97.8^{a}	97.0^{a}
	6. gly	2.3^{b}	61.3^{b}	68.8^{b}	92.3^{a}	94.5^{a}	92.3^{a}
	7. (saflufenacil + imazethapyr)	10.5^{ab}	12.0^{c}	28.8^{c}	19.0^{b}	16.8^{b}	10.3^{b}
	8. saflufenacil	3.8^{b}	10.8^{cd}	10.8^{d}	5.3^{c}	4.0^{c}	2.0^{c}
	9. (imazapyr + imazapic)	0.5^{b}	0.5^{cd}	0.0^{d}	0.0^{c}	0.0^{c}	0.0^{c}
	10. (imazapyr + imazapic) + dicamba	2.8^{b}	3.8^{cd}	3.8^{d}	3.0^{c}	2.0^{c}	1.3^{c}
	Mean	8.3	42.3	46.7	51.2	51.1	50.0
	CV (%)	11.5	8.3	11.4	10.5	8.3	7.8
Exp. 2	1. control (without application)	0.0^{d}	0.0^{c}	0.0^{c}	0.0^{b}	0.0^{b}	0.0^{b}
	2. (saflufenacil + imazethapyr) + gly + dicamba *seq.* saflufenacil + gly	12.5^{bc}	94.3^{a}	97.5^{a}	98.5^{a}	98.5^{a}	98.5^{a}
	3. saflufenacil + gly + dicamba *seq.* (saflufenacil + imazethapyr)	19.0^{ab}	96.5^{a}	98.0^{a}	98.5^{a}	98.5^{a}	98.5^{a}
	4. saflufenacil + gly + dicamba *seq.* imazethapyr	17.5^{ab}	97.3^{a}	97.8^{a}	98.8^{a}	99.0^{a}	99.0^{a}
	5. saflufenacil + gly + clethodim *seq.* (paraquat + diuron)	24.0^{a}	95.0^{a}	98.0^{a}	98.5^{a}	99.0^{a}	99.0^{a}
	6. gly + dicamba *seq.* (paraquat + diuron)	5.3^{d}	23.8^{b}	92.5^{b}	95.0^{a}	98.3^{a}	98.5^{a}
	Mean	13.1	67.8	80.6	81.5	82.2	82.3
	CV (%)	32.5	5.9	1.8	2.1	1.0	0.8
Exp. 3	1. control (without application)	0.0^{e}	0.0^{f}	0.0^{e}	0.0^{e}	0.0^{e}	0.0^{e}
	2. (saflufenacil + imazethapyr)	40.5^{c}	45.5^{c}	53.0^{c}	48.3^{c}	43.0^{c}	43.0^{c}
	3. (saflufenacil + imazethapyr)	52.8^{b}	59.5^{b}	70.8^{b}	70.5^{b}	64.8^{b}	60.5^{b}
	4. (saflufenacil + imazethapyr)	56.5^{b}	63.5^{b}	72.5^{b}	68.0^{b}	60.5^{b}	55.8^{b}
	5. (saflufenacil + imazethapyr)	52.3^{b}	59.0^{b}	68.3^{b}	62.8^{b}	61.5^{b}	58.0^{b}
	6. dicamba	24.5^{d}	30.0^{e}	33.0^{d}	31.5^{d}	25.5^{d}	23.0^{d}
	7. dicamba	35.0^{c}	39.5^{d}	45.0^{c}	41.8^{c}	39.3^{c}	33.3^{d}
	8. dicamba	37.0^{c}	41.5^{d}	46.0^{c}	41.5^{c}	38.5^{c}	33.5^{d}
	9. dicamba	44.5^{c}	50.8^{c}	54.0^{c}	50.0^{c}	44.5^{c}	43.0^{c}
	10. gly	70.8^{a}	78.0^{a}	81.8^{a}	80.8^{a}	78.0^{a}	73.8^{a}
	11. gly + dicamba	73.3^{a}	77.8^{a}	83.3^{a}	80.0^{a}	79.3^{a}	73.8^{a}
	12. gly + (saflufenacil + imazethapyr)	74.0^{a}	79.8^{a}	86.5^{a}	83.3^{a}	83.0^{a}	83.0^{a}
	13. dicamba + (saflufenacil + imazethapyr)	63.5^{a}	70.0^{a}	77.3^{b}	72.3^{a}	68.0^{a}	65.5^{b}
	14. gly + (saflufenacil + imazethapyr) + dicamba	73.3^{a}	78.8^{a}	84.5^{a}	81.5^{a}	80.5^{a}	77.5^{a}
	Mean	12.7	10.3	10.5	12.2	13.5	16.3
	CV (%)	49.8	55.3	61.1	58.0	54.7	51.7

Gly: glyphosate. *Seq*.: sequential application, 7 days after the first application. Means followed by the same letter in the column do not differ by Tukey´s (1949) test ($p < 0.05$) (for exp. 1 and 2) and Scott and Knott´s (1974) test ($p < 0.05$) (for exp. 3).

In experiment 2, all herbicide treatments were effective in controlling *R. brasiliensis*, with excellent control (≥ 98.5%) at 42 DAA. However, the controls observed in experiment 3 were in general not considered satisfactory. Only the application of glyphosate (1,440 g ae ha^{-1}) + saflufenacil + imazethapyr (26.7+75.3 g i.a. ha^{-1}) provided final control of *R. brasiliensis* greater than 80%, however without difference for application of glyphosate, glyphosate + dicamba (288 g ae ha^{-1}) and glyphosate + saflufenacil + imazethapyr + dicamba.

The control results of *C. benghalensis* in the three experiments (Table 4) are shown below. Better control percentages in experiment 1 were verified for the application of glyphosate in combination with saflufenacil + imazethapyr, saflufenacil, or flumioxazin, with at least 85.5% at 42 DAA. As observed for *R. brasiliensis*, in experiment 2, all herbicide treatments provided excellent control of *C. benghalensis* at 42 DAA (≥ 96.8%). Still in the control evaluation of *C. benghalensis*, in experiment 3, none of the treatments reached even 80% at 42 DAA. Better results were found for the application of glyphosate and in combinations with saflufenacil + imazethapyr and/or dicamba, however with a maximum of 77.5% at 42 DAA.

Table 4. *C. benghalensis* (%) at 7, 14, 21, 28, 35, and 42 days after application (DAA) of herbicides. PR, Brazil, 2017.

	Treatments	Control at DAA					
		7	14	21	28	35	42
Exp. 1	1. control (without application)	0.0c	0.0d	0.0f	0.0e	0.0d	0.0e
	2. (saflufenacil + imazethapyr) + gly	83.8ab	88.5a	92.3a	96.8a	93.8a	94.0a
	3. saflufenacil + gly	88.5a	93.3a	94.0a	96.5a	95.0a	91.0a
	4. flumioxazin + gly	77.5b	83.8a	86.8ab	91.5a	87.8a	85.5a
	5. diclosulam + gly	4.3c	15.3c	16.0e	23.5cd	22.3cd	17.8de
	6. gly	74.5b	34.3b	29.3d	35.0c	31.3c	29.3cd
	7. (saflufenacil + imazethapyr)	90.5a	86.3a	78.3c	71.3b	60.8b	53.3bc
	8. saflufenacil	88.8a	82.5a	81.0bc	80.0ab	77.8ab	74.3ab
	9. (imazapyr + imazapic)	3.8c	5.0d	1.5f	1.0e	1.0d	0.8e
	10. (imazapyr + imazapic) + dicamba	6.8c	9.8d	6.0ef	5.9de	4.8d	3.8de
	Mean	33.9	51.8	49.9	48.5	50.1	47.4
	CV (%)	11.5	8.6	9.6	9.6	16.4	20.9
Exp. 2	1. control (without application)	0.0c	0.0c	0.0c	0.0c	0.0c	0.0b
	2. (saflufenacil + imazethapyr) + gly + dicamba *seq.* saflufenacil + gly	83.3a	86.5a	96.3a	97.5a	98.8a	99.0a
	3. saflufenacil + gly + dicamba *seq.* (saflufenacil + imazethapyr)	86.3a	90.8a	92.8a	96.5a	98.0ab	98.5a
	4. saflufenacil + gly + dicamba *seq.* imazethapyr	86.3a	90.8a	94.5a	96.5a	98.0ab	98.5a
	5. saflufenacil + gly + clethodim *seq.* (paraquat + diuron)	83.8a	90.0a	94.3a	96.5a	98.8a	98.8a
	6. gly + dicamba *seq.* (paraquat + diuron)	31.3b	46.3b	68.3b	81.5b	93.3b	96.8a
	Mean	61.8	67.4	74.3	78.1	81.1	81.9
	CV (%)	11.9	6.3	8.8	5.0	2.6	1.7
Exp. 3	1. control (without application)	0.0e	0.0e	0.0f	0.0e	0.0e	0.0d
	2. (saflufenacil + imazethapyr)	39.3c	44.3c	52.0c	47.5c	41.3c	41.3c
	3. (saflufenacil + imazethapyr)	52.0b	58.8b	70.0b	69.5b	63.8b	57.5b
	4. (saflufenacil + imazethapyr)	55.8b	62.5b	71.8b	65.5b	58.8b	55.0b
	5. (saflufenacil + imazethapyr)	51.5b	58.0b	66.3b	61.0b	57.5b	55.0b
	6. dicamba	23.8d	29.3d	33.8e	30.0d	23.8d	21.3c
	7. dicamba	33.8c	38.8c	43.8d	40.8c	37.5c	32.5c
	8. dicamba	36.0c	40.8c	44.5d	40.8c	37.5c	32.5c
	9. dicamba	43.3c	49.5c	53.3c	48.8c	43.8c	42.0c
	10. gly	69.8a	76.3a	80.5a	79.5a	76.3a	72.5a
	11. gly + dicamba	72.5a	77.0a	82.0a	79.3a	77.5a	72.5a
	12. gly + (saflufenacil + imazethapyr)	73.3a	78.0a	84.3a	80.5a	80.0a	77.5a
	13. dicamba + (saflufenacil + imazethapyr)	62.5b	68.8a	76.0a	70.8a	66.3b	62.5b
	14. gly + (saflufenacil + imazethapyr) + dicamba	72.5a	78.0a	83.3a	80.5a	78.8a	75.0a
	Mean	32.3	36.8	42.8	39.6	36.0	33.8
	CV (%)	18.6	18.2	15.0	17.4	20.3	22.4

Gly: glyphosate. *Seq.*: sequential application, 7 days after the first application. Means followed by the same letter in the column do not differ by Tukey´s (1949) test ($p < 0.05$) (for exp. 1 and 2) and Scott and Knott´s (1974) test ($p < 0.05$) (for exp. 3).

Control of *C. sumatrensis* was evaluated in experiments 1 and 2 (Table 5). For the experiment 1, scores above 80% were observed until 28 DAA, however, in the subsequent assessments, there was a reduction in the control percentages, with a final control of 62.3% maximum for the application of saflufenacil + imazethapyr + glyphosate. Also, for *C. sumatrensis*, all herbicide treatments in experiment 2 were effective in control, with scores ≥ 98.5% at 42 DAA.

Table 5. *C. sumatrensis* (%) at 7, 14, 21, 28, 35, and 42 days after application (DAA) of herbicides. PR, Brazil, 2017.

	Treatments	Control at DAA					
		7	14	21	28	35	42
Exp. 1	1. control (without application)	0.0^{e}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}
	2. (saflufenacil + imazethapyr) + gly	85.0^{ab}	92.0^{a}	93.3^{a}	88.3^{a}	77.3^{a}	63.3^{a}
	3. saflufenacil + gly	87.5^{a}	94.5^{a}	95.3^{a}	84.0^{a}	63.3^{a}	52.8^{a}
	4. flumioxazin + gly	10.3^{d}	12.8^{bc}	13.3^{bc}	6.3^{c}	4.0^{c}	2.0^{c}
	5. diclosulam + gly	4.3^{e}	11.0^{bc}	10.3^{bc}	5.5^{c}	4.0^{c}	1.8^{c}
	6. gly	5.0^{e}	9.0^{bc}	9.0^{bc}	4.0^{c}	2.5^{c}	0.8^{c}
	7. (saflufenacil + imazethapyr)	65.0^{c}	87.5^{a}	81.3^{a}	62.5^{b}	40.5^{b}	31.3^{b}
	8. saflufenacil	75.8^{b}	90.0^{a}	91.5^{a}	84.3^{a}	69.8^{a}	50.3^{ab}
	9. (imazapyr + imazapic)	0.0^{e}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}
	10. (imazapyr + imazapic) + dicamba	5.8^{e}	17.0^{b}	17.5^{b}	12.5^{c}	8.0^{c}	5.5^{c}
	Mean	33.9	41.4	41.1	34.7	26.9	20.9
	CV (%)	11.5	13.7	14.1	22.1	25.7	38.1
Exp. 2	1. control (without application)	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{b}
	2. (saflufenacil + imazethapyr) + gly + dicamba *seq.* saflufenacil + gly	84.5^{a}	97.3^{a}	98.3^{a}	99.0^{a}	99.0^{a}	99.0^{a}
	3. saflufenacil + gly + dicamba *seq.* (saflufenacil + imazethapyr)	83.8^{a}	97.5^{a}	98.3^{a}	99.0^{a}	99.0^{a}	99.0^{a}
	4. saflufenacil + gly + dicamba *seq.* imazethapyr	88.8^{a}	97.8^{a}	98.5^{a}	99.0^{a}	99.0^{a}	99.0^{a}
	5. saflufenacil + gly + clethodim *seq.* (paraquat + diuron)	88.8^{a}	96.0^{a}	98.0^{a}	98.3^{a}	98.5^{a}	98.8^{a}
	6. gly + dicamba *seq.* (paraquat + diuron)	21.3^{b}	40.0^{b}	43.0^{b}	68.0^{b}	93.0^{b}	98.5^{a}
	Mean	61.2	71.4	72.7	77.2	81.4	82.4
	CV (%)	12.0	3.4	4.0	4.0	1.5	0.4

Gly: glyphosate. *Seq.*: sequential application, 7 days after the first application. Means followed by the same letter in the column do not differ by Tukey´s (1949) test ($p < 0.05$).

The control of *D. insularis* was evaluated in experiment 3, only the application of glyphosate + saflufenacil + imazethapyr + dicamba provided a control of at least 80% at 21 and 28 DAA. However, the following evaluations showed a reduction in control, with a score of 74.8% at 42 DAA (Table 6).

Table 6. *D. insularis* (%) at 7, 14, 21, 28, 35, and 42 days after application (DAA) of herbicides. PR, Brazil, 2017.

	Treatments	Control at DAA					
		7	14	21	28	35	42
Exp. 3	1. control (without application)	0.0^{e}	0.0^{e}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{e}
	2. (saflufenacil + imazethapyr)	33.5^{d}	40.0^{d}	48.8^{c}	40.0^{c}	35.0^{c}	31.3^{d}
	3. (saflufenacil + imazethapyr)	47.0^{c}	55.0^{c}	68.8^{b}	65.8^{b}	61.3^{b}	58.8^{b}
	4. (saflufenacil + imazethapyr)	56.0^{b}	63.8^{b}	74.3^{b}	71.0^{b}	66.3^{b}	63.8^{b}
	5. (saflufenacil + imazethapyr)	47.8^{c}	55.8^{c}	67.5^{b}	62.5^{b}	60.0^{b}	57.5^{b}
	6. dicamba	0.0^{e}	0.0^{e}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{e}
	7. dicamba	0.0^{e}	0.0^{e}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{e}
	8. dicamba	0.0^{e}	1.0^{e}	1.3^{d}	1.8^{d}	1.3^{d}	0.8^{e}
	9. dicamba	6.3^{e}	7.5^{e}	9.5^{d}	8.8^{d}	8.0^{d}	5.5^{e}
	10. gly	41.8^{c}	48.8^{c}	56.5^{c}	46.8^{c}	38.8^{c}	35.0^{c}
	11. gly + dicamba	41.5^{c}	45.0^{d}	52.5^{c}	47.5^{c}	40.0^{c}	32.5^{c}
	12. gly + (saflufenacil + imazethapyr)	62.5^{b}	70.5^{a}	78.0^{a}	76.0^{a}	70.0^{a}	68.0^{a}
	13. dicamba + (saflufenacil + imazethapyr)	45.8^{c}	50.5^{c}	58.8^{c}	54.5^{c}	47.5^{c}	45.0^{c}
	14. gly + (saflufenacil + imazethapyr) + dicamba	70.0^{a}	77.0^{a}	83.3^{a}	80.5^{a}	76.3^{a}	74.8^{a}
	Mean	32.3	36.8	42.8	39.6	36.0	36.8
	CV (%)	18.6	18.2	15.0	17.4	20.3	22.4

Gly: glyphosate. *Seq.*: sequential application, 7 days after the first application. Means followed by the same letter in the column do not differ by Scott and Knott's (1974) test ($p < 0.05$).

4. Discussion

The herbicide treatments in experiment 2 were effective in controlling *R. brasiliensis*, *C. benghalensis,* and *C. sumatrensis*. This can be explained by sequential application after the first application, as an increase in control is registered from the 14 DAA assessment (first evaluation after sequential application).

Thus, the results highlight the efficacy of these herbicides, such as saflufenacil, which provided excellent controls of *R. brasiliensis*, *C. benghalensis,* and *C. sumatrensis*, in combinations in the first application or sequential application. Cesco et al. (2019) also verified the efficacy of saflufenacil in controlling *Conyza* spp. (≥ 95%) at 28 DAA, in a single or sequential application, whether, or not, combined with glyphosate and/or 2,4-D.

The application of saflufenacil was also effective in different management programs in the control of *Conyza* spp. (Eubank et al. 2013; Montgomery et al. 2017; Zimmer et al. 2018; Albrecht et al. 2020). While Hedges et al. (2019) observed the efficacy of saflufenacil or saflufenacil + imazethapyr, in combinations with glyphosate in the control of *C. sumatrensis* (with scores ≥ 91%, 12 weeks after application). The application of saflufenacil + imazethapyr + glyphosate was effective in the present study in the control of *R. brasiliensis* and *C. benghalensis* (single application), and in the control of *C. sumatrensis* in different managements with sequential application.

Saflufenacil was also effective in controlling *C. benghalensis* in a study by Santos Júnior et al. (2019), as observed herein, as well as the application of glyphosate + imazethapyr (Ramires et al. 2011). These results indicate the herbicides saflufenacil and imazethapyr as alternatives for the control of *C. benghalensis*. This plant is sometimes difficult to control when only glyphosate is adopted for chemical control, given the tolerance to this herbicide (Rocha et al. 2007; Dias et al. 2013).

Diesel et al. (2018) found difficulties in controlling *R. brasiliensis* with glyphosate, with varied susceptibility according to biotype. Although it is not a species with cases of glyphosate resistance, tolerance to this herbicide is known and represents difficulties in control, as highlighted by other authors (Monquero et al. 2005; Cerdeira et al. 2011). In the present study, besides the aforementioned saflufenacil and imazethapyr, other herbicides such as flumioxazin, diclosulam, diuron, paraquat, and dicamba were effective in at least some treatment to control *R. brasiliensis*. These herbicides can be used as alternatives or supplements to glyphosate in the management of this weed.

The control of *D. insularis* was evaluated in experiment 3, as already shown, none of the treatments provided control over 80% at 42 DAA. Nonetheless, the application of glyphosate + saflufenacil + imazethapyr + dicamba at 21 and 28 DAA provided controls of 83.3 and 80.5%, respectively. Perhaps sequential applications with other herbicides may help prolong control effectiveness, as observed for the other weeds in this study in experiment 2.

It is noteworthy that no ACCase inhibitor herbicides were used, which along with glyphosate are the most used for the control of *D. insularis*. From this point of view, the results indicate that other herbicides can be used for control. This was verified by Melo et al. (2017) and Francischini et al. (2012), in which the application of ALS inhibitors herbicides (same mechanism of action as imazethapyr) was effective in controlling *D. insularis*, which corroborates the present study.

Our findings reinforce that the use of other herbicides, such as imazethapyr and saflufenacil, as alternatives or in combination with glyphosate, are effective and necessary to assist in weed resistance and/or tolerance to herbicides. As highlighted by other studies (Riar et al. 2013; Green 2018; Neve et al. 2018).

5. Conclusions

Some herbicide combinations were effective in controlling *R. brasiliensis*, *C. benghalensis*, in single application or sequential application.

Herbicide combinations were effective in controlling *C. sumatrensis* with sequential application.

Herbicide combinations in single application did not provide satisfactory final control (≥ 80%) for *D. insularis*.

The results highlight the importance of combinations and sequential applications in chemical weed control, as well as the use of other herbicides in addition to glyphosate, such as imazethapyr and saflufenacil.

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