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Herbicide efficacy in weed control increased due to by sequential application of glufosinate + saflufenacil

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ABSTRACT

The efficacy of glufosinate + saflufenacil in weed control is well known, but it remains unclear whether the sequential application of glufosinate + saflufenacil can increase the control efficacy of herbicides and what would be the best herbicide or herbicide mixtures used in the first application before subsequent application of glufosinate + saflufenacil? The objective was to evaluate the effectiveness of herbicides, followed or not by the sequential application of glufosinate + saflufenacil, in the control of *Conyza* spp. (fleabane) and *Commelina benghalensis* (Benghal dayflower) in the off-season, prior to soybean sowing. The experiment was conducted in 2020 in Palotina, Paraná (PR), using a randomized block design with four repetitions. The treatments were arranged in a factorial arrangement (19 × 2), using 19 herbicides, namely glyphosate, glufosinate, carfentrazone, saflufenacil, dicamba, and 2,4-D, alone or in mixtures, for the first application. Next, we examined the effect of subsequent application of glufosinate + saflufenacil. The results showed that subsequent glufosinate + saflufenacil application increased the effectiveness of all treatments in controlling Benghal dayflower, regardless of the herbicides used in the initial application. The combination of glufosinate + saflufenacil effectively controlled the fleabane when given as the first or sequential application. However, single application in the off season, prior to the sowing of soybeans, is not the most viable indication. Our findings highlight importance of mixing saflufenacil with carfentrazone in the control of Benghal dayflower, and with dicamba in the control of fleabane.

Keywords: *Conyza* spp., *Commelina benghalensis*, Glyphosate, Synthetic Auxins, Protoporphyrinogen oxidase (Protox) inhibitors.

Incremento na eficácia de herbicidas no controle de plantas daninhas devido a aplicação sequencial de glufosinate + saflufenacil

RESUMO

É notória a eficácia de glufosinate + saflufenacil no controle de plantas daninhas, mas qual o incremento da eficácia de controle da primeira aplicação de herbicidas devido à aplicação sequencial, ou ainda quais seriam as melhores misturas de herbicidas na primeira aplicação com a aplicação sequencial de glufosinate + saflufenacil? Objetivou-se avaliar a eficácia de herbicidas, seguidos ou não da aplicação sequencial de glufosinate + saflufenacil, no controle de *Conyza* spp. (buva) e *Commelina benghalensis* (trapoeraba) no período de entressafra, anteriormente à semeadura da soja. O experimento foi conduzido em 2020, em Palotina, Paraná (PR), utilizado delineamento em blocos casualizados, com quatro repetições. Os tratamentos foram dispostos em arranjo fatorial (19 x 2), utilizados 19 níveis para a primeira aplicação, compostos pela aplicação isolada ou em misturas de glyphosate, glufosinate, carfentrazone, saflufenacil, dicamba e 2,4-D. O segundo fator foi representado pela aplicação, ou não, em sequencial de glufosinate + saflufenacil. A aplicação sequencial incrementou a eficácia de todos os tratamentos no controle de trapoeraba, independentemente dos herbicidas utilizados na primeira aplicação. A aplicação de glufosinate + saflufenacil foi eficaz no controle da buva, seja na primeira ou na aplicação sequencial. A aplicação única em manejo de entressafra, antecedendo a soja, não é a indicação mais viável. Destaca-se a importância das misturas de saflufenacil com carfentrazone no controle de trapoeraba, e com dicamba, no controle de buva.

Palavras-chave: *Conyza* spp., *Commelina benghalensis*, Glyphosate, Auxinas sintéticas, Inibidores da protoporfirinogênio oxidase (Protox).

1. Introduction

The weed *Conyza* spp. (fleabane) is a common weed worldwide. It has an annual life cycle and herbaceous growth, with high seed production, found in various agricultural environments, such as grain crops (Moreira and Bragança, 2011). Another important weed found in different environments is *Commelina benghalensis* (Benghal dayflower), a branched perennial plant reproducing by seeds and vegetative structures (Moreira and Bragança, 2011; Lorenzi, 2014). These weeds are important in soybean and corn cultivation, as their control is made difficult by one or more of these factors: high production of propagules, dissemination of propagules by wind, and resistance or tolerance to herbicides such as glyphosate (Dauer et al., 2007).

Brazil has seen cases of *Conyza sumatrensis* (Sumatran fleabane) with multiple resistance to the herbicides chlorimuron and glyphosate (Santos et al., 2014), single resistance to paraquat (Zobiole et al., 2019), and single or multiple resistance to these and other herbicides such as photosystem II inhibitors and synthetic auxins (Pinho et al., 2019; Albrecht et al., 2020a; Queiroz et al., 2020). Moreover, Benghal dayflower is recognized to be tolerant to some herbicides, for example, glyphosate (Dias et al., 2013; Santos et al., 2015). In addition to these difficulties in the control and resistance/tolerance of these weeds, studies have shown the high interference of these species in crops such as soybeans and corn. In fact, 2.7 m^2 of fleabane plants can reduce soybean yield by 50% (Trezzi et al., 2015).

Among the factors that lead to the selection of herbicide-resistant weed biotypes is the use of the same herbicides with strong selection pressure, which leads to the emergence of resistant biotypes. Thus, the use of herbicides with different action mechanisms or herbicide combinations, as well as the adoption of tools other than chemical control, are fundamental in preventing the emergence of resistant weed biotypes and in their management (Gage et al., 2019; Deffontaines et al., 2020).

Different herbicides, in combination with glyphosate, can be effective in the control of fleabane and/or Benghal dayflower in inter-harvest management, in particular saflufenacil (Santos Junior et al., 2019; Piasecki et al., 2020; Albrecht et al., 2022a), auxin mimetics (Frene et al., 2018), and glufosinate (Tahmasebi et al., 2018). The synergistic effects of some herbicide combinations in weed control have been reported, for example, the combination of glufosinate + saflufenacil (Takano et al., 2020).

The application of glyphosate, alone or combined with saflufenacil, can be conducted at different times in subsequent application in pre-seeding desiccation. The application of glyphosate, alone or in a combination, followed by the application of glufosinate, effectively controlled fleabane (Albrecht et al., 2020b). Similar effects were observed by Meyer and Norsworthy (2020) for the subsequent application of glufosinate in grass and broadleaf control as well as by Bottcher et al. (2022) for the combined application of saflufenacil in fleabane and Benghal dayflower.

The efficacy of glufosinate + saflufenacil in weed control is well known, but it is unclear whether the subsequent application of glufosinate + saflufenacil can increase the control efficacy of herbicides and what would be the best herbicide or herbicide mixtures used in the first application before sequential application of glufosinate + saflufenacil? Therefore, the objective of this study was to evaluate the effectiveness of sequential application of glufosinate + saflufenacil in improving the efficacy of herbicides in controlling fleabane and Benghal dayflower at the off-season period, prior to the sowing of soybean.

2. Material and Methods

The experiment had a randomized block design with four repetitions, and the experimental units were composed of 3 × 5 m plots. The treatments were arranged in a factorial arrangement (19 × 2). The first factor was the first application of herbicides alone or in combination (Table 1). The second factor was the sequential application (with or without) of glufosinate (Finale®, 500 g a.i. ha^{-1}) + saflufenacil (Heat®, 35 g a.i. ha^{-1}) + mineral oil (0.5% v/v) at 24 days after the first application of herbicides (DAA).

The dates and environmental conditions during the herbicide applications are described in Table 2. All herbicide applications were performed using a CO_2 pressurized backpack sprayer equipped with six AIXR 110.015 tips at a pressure of 2 kgf cm^{-2} and speed of 3.6 km h^{-1}, providing an application volume of 150 L ha^{-1}. The study area had a high infestation of Benghal dayflower, with heavily branching plants, and a low infestation of fleabane, with most plants having between 10 and 15 leaves.

Weed control was evaluated at 28, 35, and 42 DAA. These evaluations were performed by visual analysis at each experimental unit (0 for no injury, up to 100% for plant death), considering, in this case, significantly visible symptoms in the plants, according to their development (Velini et al., 1995). Analysis of variance (ANOVA) was performed by the F-test ($p < 0.05$). For evaluating the effect of the first herbicide application, the means of the treatments were grouped by the Scott & Knott (1974) test ($p < 0.05$). For examining the effect of the sequential herbicide application, the means were compared by the F-test ($p < 0.05$). The Sisvar 5.6 program (Ferreira, 2011) was used for the analysis.

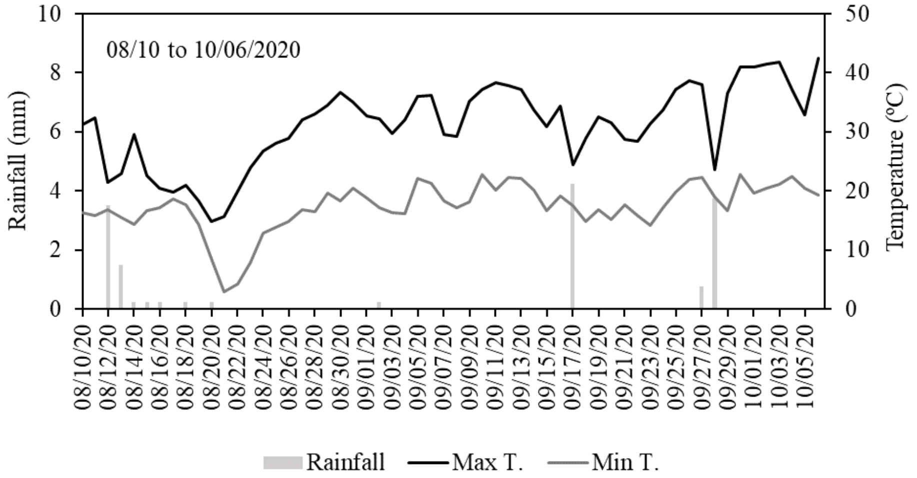

Figure 1. Rainfall, maximum temperature, and minimum temperature during the experiment. Source: Stationary weather station located in Palotina, PR, Brazil (24°10′44.5″S 53°50′16.4″W).

Table 1. First application of herbicides at post-emergence of Benghal dayflower and fleabane. Palotina, PR, 2020.

Herbicides¹	Rate²
	g a.i. or a.e. ha^{-1}
Without application	-
Glufosinate	500
Glufosinate	700
Glyphosate + glufosinate	1000 + 500
Glyphosate + saflufenacil	1000 + 49
Glyphosate + carfentrazone	1000 + 30
Glufosinate + saflufenacil	500 + 35
Glufosinate + saflufenacil	500 + 49
Glufosinate + carfentrazone	500 + 30
Glyphosate + carfentrazone + saflufenacil	1000 + 20 + 24.5
Glufosinate + carfentrazone + saflufenacil	500 + 20 + 24.5
Glyphosate + saflufenacil + 2,4-D	1000 + 49 + 804
Glyphosate + saflufenacil + dicamba	1000 + 49 + 288
Glyphosate + carfentrazone + 2,4-D	1000 + 30 + 804
Glyphosate + carfentrazone + dicamba	1000 + 30 + 288
Glufosinate + saflufenacil + 2,4-D	500 + 49 + 804
Glufosinate + saflufenacil + dicamba	500 + 49 + 288
Glufosinate + carfentrazone + 2,4-D	500 + 30 + 804
Glufosinate + carfentrazone + dicamba	500 + 30 + 288

¹ Commercial products: Finale® (glufosinate), Zapp® QI 620 (glyphosate), Heat® (saflufenacil), Aurora® 400 EC (carfentrazone), DMA® 806 BR (2,4-D), Atectra® (dicamba). Adding mineral oil (0.5% v/v) in all treatments. ² a.i. (active ingredient) for glufosinate, saflufenacil, and carfentrazone; a.e. (acid equivalent) for glyphosate, 2,4-D, and dicamba.

Table 2. Dates and weather conditions during herbicide applications.

	Date	Wind	Temperature	Relative humidity
		km h^{-1}	ºC	%
First application	08/25/2020	6.5	24.9	58.7
Sequential application	09/18/2020	2.4	27.2	62.7

3. Results and Discussion

Both the first and sequential applications, as well as their interaction, showed significant efficacy ($p < 0.05$) in controlling Benghal dayflower and fleabane in all evaluations (Table 3). Therefore, the interaction between the first and sequential applications was presented. The sequential application of glufosinate + saflufenacil increased the effectiveness of all herbicides in the initial application in controlling Benghal dayflower at 28, 35, and 42 DAA.

The subsequent application was the predominating factor in the control of Benghal dayflower; at 42 DAA, the control was ≥ 95.8% with no differences from the herbicides in the initial application, except for the glufosinate + saflufenacil treatment without an initial herbicide application at only 68.8%. In the analysis of herbicide application without subsequent glufosinate + saflufenacil application, the combination of three herbicides, namely glyphosate or glufosinate + Protox inhibitor (carfentrazone or saflufenacil) + synthetic auxin (2,4-D or dicamba), showed the highest efficacy.

However, at 42 DAA, the percentage of control peaked at 60% for glufosinate + saflufenacil + 2,4-D, which indicates that the predominating factor for effective control of Benghal dayflower is the sequential application of glufosinate + saflufenacil, regardless of the herbicides used in the initial application; thus, this sequential glufosinate + saflufenacil application cannot fail to be performed (Table 4).

Sequential application of glufosinate was important in Benghal dayflower control, as it increased the efficacy of chlorimuron or s-metolachlor, alone or in combination with glyphosate; in contrast, carfentrazone alone or in mixture with glyphosate achieved 100% control even without subsequent application of glufosinate (Jerônimo et al., 2021). Furthermore, subsequent application of saflufenacil or other herbicides was effective after the initial application of glyphosate + Protox inhibitor + dicamba in controlling Benghal dayflower (Bottcher et al., 2022).

These results of previous studies (Correia et al., 2008; Lopes-Ovejero et al., 2013), and that of the present study, highlight the importance of sequential applications and/or mixtures of herbicides in Benghal dayflower control. In particular, Protox-inhibiting herbicides or glufosinate was effective in controlling Benghal dayflower (Ferreira et al., 2017; Santos Junior et al., 2019). In the present study, sequential application of glufosinate + saflufenacil after the first application of herbicides was effective and a predominant factor in controlling this weed.

Glufosinate was the leading herbicide for the control of fleabane, even without sequential application, almost in all mixtures among the most effective treatment, especially at a rate of 700 g a.i. ha^{-1}. The effectiveness of glufosinate is reiterated by the results observed for sequential application; even without an initial herbicide application, glufosinate + saflufenacil provided 99.5% control (Table 5).

In the analysis of initial herbicide application without sequential glufosinate + saflufenacil application, the importance of the herbicides glufosinate and saflufenacil is evident, as the final control score for the treatments glyphosate + carfentrazone and glyphosate + carfentrazone was 0% and 7.8%, respectively. On the contrary, treatments with saflufenacil in mixtures with glyphosate or glyphosate + 2,4-D, but without glufosinate, provided final control between 67.5% and 71.3% (Table 5).

The results show that glufosinate, alone or in a mixture with Protox inhibitors, effectively controls fleabane after a single application. The application of glufosinate effectively controlled evening primrose, even when isolated (Tahmasebi et al., 2018). In other weed species, saflufenacil and glufosinate were more effective in controlling and reducing the density when applied in combination than alone (Jhala et al., 2013).

Takano et al. (2020) and Waggoner et al. (2011) also observed the synergistic effect of glufosinate + saflufenacil for weed control. Moreover, saflufenacil showed efficacy in combination with auxins and glyphosate, and studies have indicated the synergistic effects of saflufenacil and glyphosate in the control of fleabane (Dalazen et al., 2015; Piasecki et al., 2020).

In general, the complex management employed in this study successfully increased weed control. Other studies also highlight the effectiveness of glufosinate herbicides and/or Protox inhibitors, such as saflufenacil or carfentrazone, in controlling fleabane or Benghal dayflower (Brito et al., 2017; Krolikowski et al., 2017; Frene et al., 2018; Hedges et al., 2019). These herbicide combinations are even more critical during the paraquat ban in Brazil, making it among the main substitutes of paraquat used for controlling fleabane and Benghal dayflower (Albrecht et al., 2022b). Therefore, the present study points to glufosinate as a substitute for paraquat in pre-sowing burndown to control Benghal dayflower and fleabane, with efficacy that can be increased by combination with Protox-inhibiting herbicides.

Table 3. ANOVA results (F-test) for the control (%) of Benghal dayflower and fleabane at 28, 35, and 42 days after the first application (DAA) of herbicides.

	Benghal dayflower			Fleabane		
Source	28 DAA	35 DAA	42 DAA	28 DAA	35 DAA	42 DAA
First application	44.8*	20.8*	28.3*	454.3*	475.1*	886.9*
Sequential application	2026.1*	2783.7*	4538.1*	1494.5*	2623.2*	7988.0*
Interaction	11.3*	14.2*	9.3*	418.4*	469.1*	884.3*
Mean	71.2	69.7	67.7	92.1	90.1	87.5
CV (%)	7.3	7.6	7.9	2.3	2.4	1.8

* Significant ($p < 0.05$).

Table 4. Benghal dayflower control at 28, 35, and 42 days after the initial application (DAA) of herbicides, with or without sequential application of glufosinate + saflufenacil (500 + 35 g a.i. ha^{-1}) at 21 DAA.

1st application[1] (rate[2] g a.i. or a.e. ha^{-1})	21 DAA[3]	28 DAA		35 DAA		42 DAA	
		Without	With	Without	With	Without	With
				%			
Without application	0.0	0.0 Bf	58.8 Ab	0.0 Bf	87.5 Aa	0.0 Bf	68.8 Ab
Glu (500)	47.5	42.5 Bd	87.0 Aa	33.8 Be	90.0 Aa	26.3 Bd	95.8 Aa
Glu (700)	63.8	51.3 Bd	90.0 Aa	41.3 Bd	91.3 Aa	31.3 Bd	98.5 Aa
Gly + glu (1000 + 500)	58.8	51.8 Bd	91.0 Aa	47.5 Bd	93.8 Aa	42.5 Bb	98.0 Aa
Gly + saflufenacil (1000 + 49)	56.3	56.3 Bc	90.0 Aa	54.5 Bc	90.0 Aa	52.5 Ba	94.8 Aa
Gly + carfentrazone (1000 + 30)	67.0	53.8 Bc	90.0 Aa	47.0 Bd	92.5 Aa	27.5 Bd	98.5 Aa
Glu + saflufenacil (500 + 35)	47.5	30.0 Be	89.8 Aa	27.5 Be	91.3 Aa	17.5 Be	97.0 Aa
Glu + saflufenacil (500 + 49)	51.3	34.3 Be	94.5 Aa	33.8 Be	95.3 Aa	27.5 Bd	98.5 Aa
Glu + carfentrazone (500 + 30)	63.8	50.0 Bd	94.0 Aa	47.5 Bd	93.3 Aa	37.5 Bc	98.8 Aa
Gly + carfentrazone + saflufenacil (1000 + 20 + 24.5)	72.5	59.3 Bc	92.5 Aa	52.5 Bc	94.3 Aa	33.8 Bd	99.0 Aa
Glu + carfentrazone + saflufenacil (500 + 20 + 24.5)	79.3	65.0 Bb	94.8 Aa	53.8 Bc	92.3 Aa	40.0 Bc	99.3 Aa
Gly + saflufenacil + 2,4-D (1000 + 49 + 804)	63.8	61.3 Bb	90.0 Aa	60.0 Bb	92.5 Aa	52.5 Ba	99.3 Aa
Gly + saflufenacil + dicamba (1000 + 49 + 288)	55.0	55.0 Bc	89.5 Aa	51.3 Bc	90.0 Aa	55.0 Ba	97.5 Aa
Gly + carfentrazone + 2,4-D (1000 + 30 + 804)	90.8	70.5 Bb	96.0 Aa	62.5 Bb	96.8 Aa	53.8 Ba	99.8 Aa
Gly + carfentrazone + dicamba (1000 + 30 + 288)	83.0	65.0 Bb	95.0 Aa	55.8 Bc	94.0 Aa	47.5 Bb	99.0 Aa
Glu + saflufenacil + 2,4-D (500 + 49 + 804)	87.5	83.0 Ba	95.8 Aa	71.3 Ba	96.3 Aa	60.0 Ba	99.8 Aa
Glu + saflufenacil + dicamba (500 + 49 + 288)	57.5	51.3 Bd	91.0 Aa	48.8 Bd	90.8 Aa	43.8 Bb	98.5 Aa
Glu + carfentrazone + 2,4-D (500 + 30 + 804)	79.3	66.3 Bb	91.8 Aa	58.8 Bb	93.5 Aa	46.3 Bb	99.8 Aa
Glu + carfentrazone + dicamba (500 + 30 + 288)	55.0	47.5 Bd	91.3 Aa	46.3 Bd	91.8 Aa	37.5 Bc	98.5 Aa

[1] Gly (glyphosate), glu (glufosinate). [2] a.i. (active ingredient) for glufosinate, saflufenacil, and carfentrazone; and a.e. (acid equivalent) for glyphosate, 2,4-D, and dicamba. [3] Control at 21 DAA, when the sequential application was performed. * Means followed by the same lowercase letter, for the first application, do not differ from each other according to the Scott & Knott (1974) test at the 5% level. Means followed by the same capital letter, for sequential application, do not differ from each other by the F-test at the 5% level.

Table 5. Control of fleabane at 28, 35, and 42 days after the first application (DAA) of herbicides, with or without sequential application of glufosinate + saflufenacil (500 + 35 g a.i. ha^{-1}) at 21 DAA.

1st application¹ (rate² g a.i. or a.e. ha^{-1})	21 DAA³	28 DAA		35 DAA		42 DAA	
		Without	With	Without	Com	Sem	Without
				%			
Without application	0.0	0.0 Be	96.5 Aa	0.0 Bg	99.0 Aa	0.0 Bh	99.5 Aa
Glu (500)	98.8	98.0 Aa	99.0 Aa	92.8 Bb	99.0 Aa	82.5 Bd	99.0 Aa
Glu (700)	98.8	98.5 Aa	99.0 Aa	97.8 Aa	99.0 Aa	92.5 Bb	99.5 Aa
Gly + glu (1000 + 500)	93.8	98.5 Aa	99.0 Aa	94.3 Bb	99.0 Aa	82.5 Bd	99.0 Aa
Gly + saflufenacil (1000 + 49)	98.5	98.8 Aa	99.0 Aa	83.8 Bc	99.0 Aa	71.3 Be	99.0 Aa
Gly + carfentrazone (1000 + 30)	10.5	6.3 Bd	97.3 Aa	4.0 Bf	98.5 Aa	0.0 Bh	99.0 Aa
Glu + saflufenacil (500 + 35)	99.0	99.0 Aa	99.0 Aa	95.0 Bb	99.0 Aa	86.5 Bc	99.0 Aa
Glu + saflufenacil (500 + 49)	99.0	99.0 Aa	99.0 Aa	99.0 Aa	99.0 Aa	99.0 Aa	99.5 Aa
Glu + carfentrazone (500 + 30)	99.0	99.0 Aa	99.3 Aa	98.0 Aa	99.0 Aa	93.5 Ab	99.0 Aa
Gly + carfentrazone + saflufenacil (1000 + 20 + 24,5)	98.8	98.5 Aa	99.0 Aa	97.5 Aa	99.0 Aa	92.3 Bb	99.0 Aa
Glu + carfentrazone + saflufenacil (500 + 20 + 24,5)	99.3	99.0 Aa	99.0 Aa	99.0 Aa	99.0 Aa	97.5 Ba	99.0 Aa
Gly + saflufenacil + 2,4-D (1000 + 49 + 804)	90.0	90.5 Bb	99.0 Aa	75.0 Bd	99.0 Aa	67.5 Bf	99.0 Aa
Gly + saflufenacil + dicamba (1000 + 49 + 288)	98.3	98.0 Aa	99.0 Aa	99.0 Aa	99.0 Aa	99.3 Aa	99.5 Aa
Gly + carfentrazone + 2,4-D (1000 + 30 + 804)	46.3	46.3 Bc	98.8 Aa	23.8 Be	98.8 Aa	7.8 Bg	99.0 Aa
Gly + carfentrazone + dicamba (1000 + 30 + 288)	87.5	98.3 Aa	98.8 Aa	98.5 Aa	99.0 Aa	99.3 Aa	99.3 Aa
Glu + saflufenacil + 2,4-D (500 + 49 + 804)	98.5	99.0 Aa	99.0 Aa	93.3 Bb	99.0 Aa	86.0 Bc	99.0 Aa
Glu + saflufenacil + dicamba (500 + 49 + 288)	99.0	99.5 Aa	99.5 Aa	99.5 Aa	99.5 Aa	99.0 Aa	99.5 Aa
Glu + carfentrazone + 2,4-D (500 + 30 + 804)	98.0	98.5 Aa	99.0 Aa	97.0 Aa	99.0 Aa	92.3 Bb	99.0 Aa
Glu + carfentrazone + dicamba (500 + 30 + 288)	98.3	98.5 Aa	99.0 Aa	96.3 Aa	99.0 Aa	92.8 Bb	99.3 Aa

¹ Gly (glyphosate), glu (glufosinate). ² a.i. (active ingredient) for glufosinate, saflufenacil, and carfentrazone; and a.e. (acid equivalent) for glyphosate, 2,4-D, and dicamba. ³Control at 21 DAA, when the sequential application was performed. * Means followed by the same lowercase letter, for the first application, do not differ from each other according to the Scott & Knott (1974) test at the 5% level. Means followed by the same capital letter, for sequential application, do not differ from each other by the F-test at the 5% level.

4. Conclusions

The sequential application of glufosinate + saflufenacil increased the effectiveness of all herbicide treatments in controlling Benghal dayflower, regardless of the herbicides used in the first application. The application of glufosinate + saflufenacil produced effective weed control effect both as the first and sequential application. They were also effective in combination with other herbicides, especially dicamba.

Single application in the off-season period, prior to soybeans, is sometimes not the best indication. However, evaluations in a single application revealed the importance of mixture with saflufenacil and carfentrazone in the control of Benghal dayflower and the combination with dicamba in the control of fleabane.

Authors' Contribution

Alfredo Junior Paiola Albrecht contributed to the conceptualization of the study, supervision, execution of the experiment, and final correction of the manuscript. Leandro Paiola Albrecht contributed to the conceptualization of the study, supervision, execution of the experiment, and final correction of the manuscript. André Felipe Moreira Silva contributed to the analysis and interpretation of results, writing of the manuscript and final correction of the manuscript.

Rafaela Alenbrant Migliavacca contributed to the analysis and interpretation of results, and final correction of the manuscript. Willian Felipe Larini contributed to the execution of the experiment, data collection, and final correction of the manuscript. Rogério Kosinski contributed to the conceptualization of the study, interpretation of results and final correction of the manuscript. Marcelo Katakura contributed to the conceptualization of the study interpretation of results and final correction of the manuscript.

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