Association of quizalofop-P-tefuril to 2,4-D in hairy fleabane (*Conyza bonariensis*) control: is the antagonism reciprocal to that observed in sourgrass (*Digitaria insularis*)?

Associação de quizalofop-P-tefuril ao 2,4-D no controle de buva (*Conyza bonariensis*): o antagonismo é recíproco ao observado em capim-amargoso (*Digitaria insularis*)?

Asociación de quizalofop-P-tefuril con 2,4-D en el control de la buva (*Conyza bonariensis*): ¿es el antagonismo recíproco al observado en la hierba amarga (*Digitaria insularis*)?

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ABSTRACT
The antagonism between auxinic herbicides and graminicides on poaceae weeds is widely known. However, the reciprocal antagonism between these herbicides in the control of eudicots is not known. This study aimed to evaluate the effect of adding quizalofop-P-tefuril and/or adjuvant to 2,4-D in the control of hairy fleabane (*Conyza bonariensis*). The treatments were organized in factorial (7 x 2 x 2), with seven doses of 2,4-D, presence or absence of quizalofop-P-tefuril, and presence or absence of adjuvant alkyl ester ethoxylate of phosphoric acid. Treatments were applied in hairy fleabane plants at 12-leaf rosette-stage. Weed control was evaluated at 14, 21, 28 and 35 days after the treatment (DAT), in addition to relative shoot dry mass (SDM) determination at 35 DAT. The addition of fluazifop-P-tefuril to 2,4-D results in antagonism in the control of hairy fleabane only when 2,4-D is applied at doses lower than recommended (less than 1,005 g a.e. ha^{-1}). The addition of adjuvant improves the efficacy of 2,4-D, offsetting the negative effect caused by the addition of quizalofop-P-tefuril. However, at doses of 2,4-D from the recommendation (1,005 g a.e. ha^{-1}), the addition of adjuvant is not necessary for the control of haity fleabane with up to 12 leaves. Therefore, it is concluded that the antagonism between quizalofop-P-tefuril and 2,4-D is reciprocal, but it depends on the dose of 2,4-D and the absence of adjuvant to the spray solution.

Keywords: ACCase, adjuvants, *Conyza* spp., herbicide mixture, weed control.

RESUMO
O antagonismo entre herbicidas auxínicos e graminicidas em plantas daninhas Poaceae é amplamente conhecido. Contudo, o antagonismo recíproco entre estes herbicidas no controle de eudicotiledôneas não é conhecido. Este estudo teve como objetivo avaliar o efeito da adição de quizalofop-P-tefuril e/ou adjuvante ao 2,4-D no controle da buva (*Conyza bonariensis*). Os tratamentos foram organizados em fatorial (7 x 2 x 2), com sete doses de 2,4-D, presença ou ausência de quizalofop-P-tefuril e presença ou ausência de adjuvante éster alquílico etoxilado de ácido fosfórico. Os tratamentos foram aplicados em plantas de buva no estágio de roseta, com 12 folhas. O controle das plantas daninhas foi avaliado aos 14, 21, 28 e 35 dias após o tratamento (DAT), além da determinação da massa seca relativa da parte aérea (MSPA) aos 35 DAT. A adição de fluazifop-P-tefuril ao 2,4-D resultou em antagonismo no controle de buva somente quando o 2,4-D é aplicado em doses inferiores às recomendadas (menos de 1.005 g e.a. ha-1). A adição do adjuvante melhora a eficácia do 2,4-D, compensando o efeito negativo causado pela adição de quizalofop-P-tefuril. Porém, nas doses de 2,4-D a partir da recomendada (1.005 g e.a. ha-1) a adição de adjuvante não é necessária para o controle de buva com até 12 folhas. Portanto, conclui-se que o antagonismo entre quizalofop-P-tefuril e 2,4-D é recíproco, mas depende da dose de 2,4-D e da ausência de adjuvante na calda.

Palavras-chave: ACCase, Adjuvantes, *Conyza* spp., Mistura de herbicidas, Controle de plantas daninhas.

RESUMEN
El antagonismo entre herbicidas auxínicos y graminicidas en malas hierbas de Poaceae es ampliamente conocido. Sin embargo, se desconoce el antagonismo recíproco entre estos herbicidas en el control de eudicots. El objetivo de este estudio fue evaluar el efecto de la adición de quizalofop-P-tefuril y/o un adyuvante al 2,4-D en el control de la buva (*Conyza bonariensis*). Los tratamientos

se organizaron en un diseño factorial (7 x 2 x 2), con siete dosis de 2,4-D, la presencia o ausencia de quizalofop-P-tefuril y la presencia o ausencia del adyuvante éster alquilo etoxilado de ácido fosfórico. Los tratamientos se aplicaron a plantas de malas hierbas en la fase de roseta, con 12 hojas. El control de las malas hierbas se evaluó a los 14, 21, 28 y 35 días después del tratamiento (DAT), además de determinar la masa seca relativa de la parte aérea (MSPA) a los 35 DAT. La adición de fluazifop-P-tefuril a 2,4-D produjo antagonismo en el control de malas hierbas sólo cuando 2,4-D se aplicó a dosis inferiores a las recomendadas (menos de 1,005 g e.a. ha-1). La adición del coadyuvante mejora la eficacia del 2,4-D, compensando el efecto negativo causado por la adición de quizalofop-P-tefuril. Sin embargo, a dosis de 2,4-D superiores a la recomendada (1,005 g e.a. ha-1), la adición de adyuvante no es necesaria para controlar malas hierbas con hasta 12 hojas. Por tanto, se puede concluir que el antagonismo entre quizalofop-P-tefuril y 2,4-D es recíproco, pero depende de la dosis de 2,4-D y de la ausencia de adyuvante en la pulverización.

Palabras clave: ACCase, Adyuvantes, *Conyza* spp., Mezcla de herbicidas, Control de malas hierbas.

1 INTRODUCTION

Weeds are among the main problems in crops around the world, reducing productivity and quality, and increasing production costs (Chauan et al. 2020; Adegas et al. 2017). In addition, weeds can act as alternative hosts for pests, pathogens and nematodes (Dalazen et al. 2017; Giraldelli et al. 2017). Among the species with the highest occurrence and the greatest concern among farmers is *Conyza* spp. (Mendes et al. 2021). In Brazil there are three main species of *Conyza*: C. *bonariensis* (hairy fleabane), *C. canadensis* (horseweed) and *C. sumatrensis* (Sumatran fleabane). For all species there are records of herbicide resistance, including resistance to glyphosate and other mechanisms of action (Albrecht et al. 2020; Heap 2024).

With resistance to glyphosate, chemical control of *Conyza* spp. has been carried out with other herbicides, including 2,4-D (2,4 dichlorophenoxyacetic acid). This is a synthetic auxin that has excellent control over eudicotyledonous weeds, such as hairy fleabane (Soares et al. 2012). However, this herbicide is not efficient in monocots (Cobb and Reade 2010), which requires the association of other herbicides when the infestation is composed of weeds of different classes. A very common example in Brazil is the occurrence of *Conyza* spp. and sourgrass (*Digitaria insularis*), both resistant to glyphosate (Adegas et al. 2017; Heap 2024).

For the control of sourgrass, acetyl-CoA carboxylase inhibitor herbicides (ACCase) are widely used and efficient, including aryloxyphenoxypropanoates (fops) and cyclohexanediones (dims) (Presoto et al. 2020). Examples of ACCase-inhibiting herbicides are clethodim, sethoxidim, haloxyfop and quizalofop (Cobb and Reade 2010). However, although efficient, the mixture of ACCase inhibitors with 2,4-D results in antagonism, reducing the effectiveness of quizalofop-P-tefuryl by 39% in the control of sourgrass (Gomes et al. 2020). Similarly, antagonism between 2,4-

D and ACCase inhibitors has already been observed in other weeds such as ryegrass (*Lolium multiflorum*) and oats (*Avena fatua*) (Todd and Stobbe 1980; Trezzi et al. 2007).

Although the antagonism between synthetic auxins and ACCase inhibitors against poaceae is known, the reciprocity of the antagonism is still unknown. In other words, is the control of hairy fleabane with 2,4-D also reduced with the association of ACCase inhibitors? In studies that evaluated the control of grasses, the authors observed that the antagonism was due to the lower absorption of the graminicide when mixed with 2,4-D (Todd and Stobbe 1980; Gomes et al. 2020). Therefore, it is also hypothesized that the addition of adjuvant to the mixture can alter the response of weeds, since these compounds act directly on the absorption of herbicides (Castro et al. 2018). Therefore, the objective of this work was to evaluate the effect of adding quizalofop-P-tefuryl to 2,4-D on the control of post-emergence hairy fleabane, as well as the effect of adding adjuvant to the spray solution.

2 MATERIAL AND METHODS

Origin and production of plant material

Glyphosate-resistant hairy fleabane (*Conyza bonariensis*) seeds were collected in Dois Irmãos das Missões, RS, and sown on the surface of a tray containing sieved organic substrate, at a temperature of 25°C. The substrate was irrigated periodically, keeping it with humidity close to the field capacity. When the seedlings had three leaves, they were individually transplanted into pots with a capacity of 1 L, filled with substrate formed by a mixture of oxisol and sand (2:1), with addition of dolomitic limestone, in the proportion of 5 g kg^{-1} of substrate, and NPK fertilizer (05-20-20), in the proportion of 2.5 g kg^{-1} of substrate. The pots were irrigated daily, keeping the humidity close to the field capacity.

Experimental design and treatments

The experiment was carried out in a completely randomized design, with four replications per treatment. The treatments were organized in triple factorial (7 x 2 x 2), with seven doses of 2,4-D: 0, 125.2, 251.25, 502.5, 1,005, 2,010 and 4,020 g a.e. ha^{-1} (DMA 806 BR, 670 g a.e. L^{-1}, Corteva, Brazil), presence or absence of 72 g a.i. ha^{-1} quizalofop-P-tefuryl (Panther 120 EC, 120 g a.i. L^{-1}, UPL, Brazil) and presence or absence of 0,5% (v/v) phosphoric acid ethoxylated alkyl ester adjuvant (Lanzar, 280 g L^{-1}, UPL, Brazil), totaling 28 treatments. The dose of 2,4-D recommended by the manufacturer for the control of hairy fleabane is 1,005 g a.e. ha^{-1}, then considered as dose X. Thus, 2,4-D dose-response curves were organized, having three doses below (X/2, X/4 and X/8) and two doses above the recommended (2X and 4X), in addition to treatment without application of 2,4-D.

Application of treatments

The treatments were applied when the hairy fleabane plants were in the rosette stage, with 12 leaves. The application was carried out with a CO_2 pressurized back sprayer, with a bar with two tips TJ 110.02, spaced 50 cm apart. The working pressure used was 30 psi, with a displacement speed of 1 m s^{-1}, which resulted in a spray volume equivalent to 150 L ha^{-1}. The treatments were applied in an outdoor environment, between 4:30 pm and 5:30 pm, with adequate conditions of temperature (25°C) and relative air humidity (70%). At the time of application of treatments, the sky was sunny and the wind speed was approximately 3 km h^{-1}.

Evaluations

Visual control evaluations were performed at 14, 21, 28 and 35 days after the treatments (DAT). For this, zero-100 percentage scale was used, where zero means absence of symptoms and 100 corresponds to total control (death) of the plants. At 35 DAT, the plants were cut at ground level and the samples were individually packed in paper bags. Afterwards, the samples were placed in an oven (65°C) for 72 h to obtain the shoot dry mass (SDM).

Data analysis

Data were subjected to analysis of variance (ANOVA) using the RStudio statistical package. The control values (y) were transformed to $\sqrt{y}$ so that the ANOVA assumptions were met. Complementary analysis of the effect of 2,4-D doses (quantitative factor) was performed by means of logistic-type sigmoidal regression adjustment

$$y = \frac{a}{\left[1 + \left(\frac{x}{x0}\right)^{b}\right]}$$

where “y” is the percentage of control or SDM; “x” the dose of the herbicide; “a” is the difference between the maximum and minimum points of the curve, “x0” is the dose that provides 50% of the variable response (C_{50}) and “b” is the slope of the curve at x0. The comparison between the levels of qualitative factors (addition or not of quizalofop-P-tefuryl and/or adjuvant) was performed using the Tukey test ($p < 0.05$).

3 RESULTS

The control results indicate that both the effect of the addition of quizalofop-P-tefuryl and adjuvant depended on the dose of the 2,4-D, indicating an interaction between the evaluated factors.

At 14 DAT, the addition of quizalofop-P-tefuryl resulted in a reduction in hairy fleabane control for most doses of 2,4-D in the absence of adjuvant (Figure 1A and Table 1). At the recommended dose of 2,4-D (1,005 g a.e. ha^{-1}), the reduction in the control was from 31% to 21% with the addition of the graminicide. However, the addition of adjuvant to 2,4-D resulted in a significant increase in hairy fleabane control for most doses (except for 251.25 and 4,020 g a.e. of 2,4-D ha^{-1}), offsetting the negative effect caused by the addition of quizalofop-P-tefuryl.

Figure 1. Hairy fleabane (*Conyza bonariensis*) control at 14 (A), 21 (B), 28 (C) and 35 (D) days after the treatment in response to application of 2,4-D alone or mixed with quizalofop-P-tefuryl (fop) and/or adjuvant (adj.).

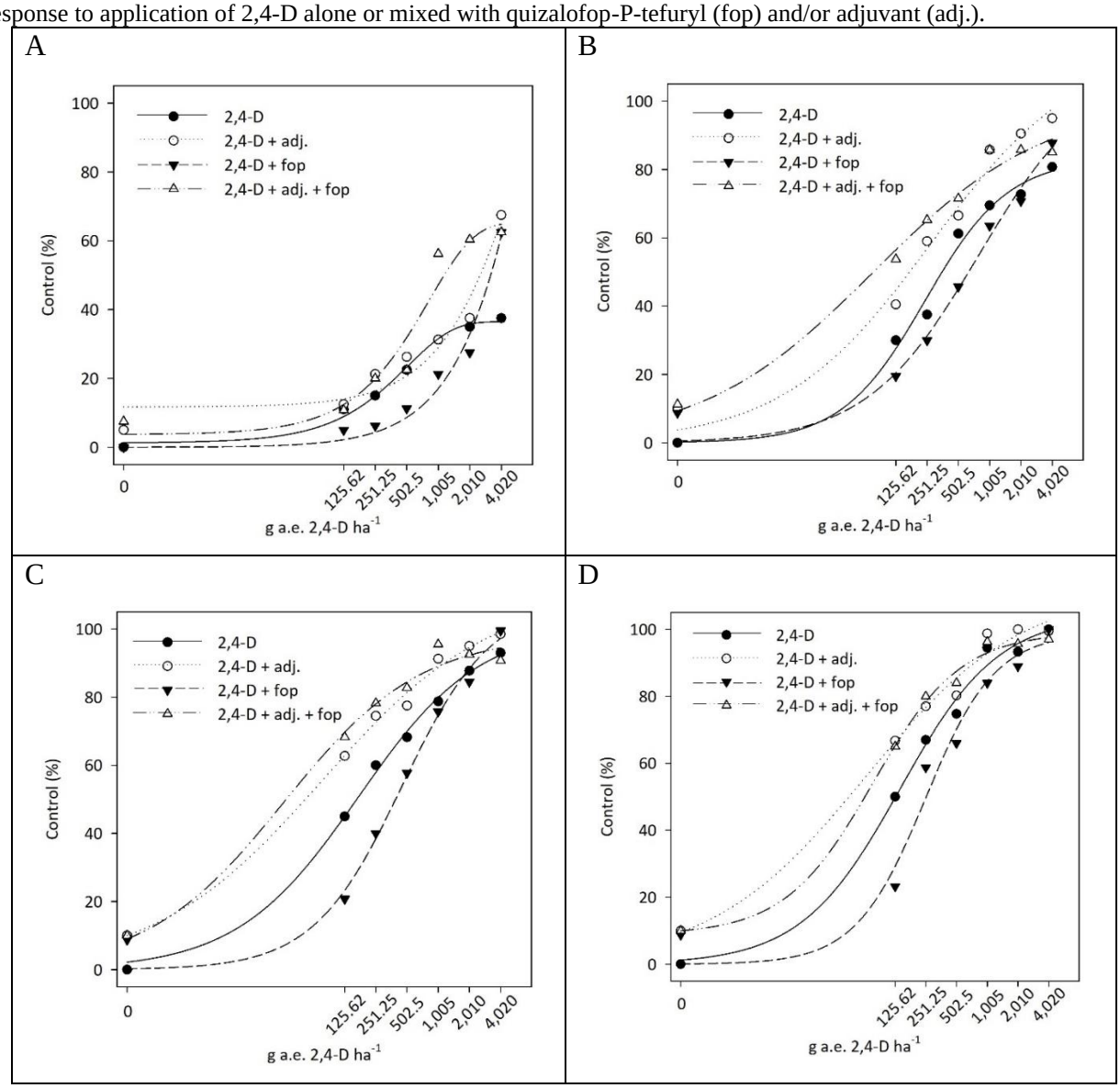

Table 1. Unfolding of the interaction of evaluated factors on hairy fleabane (*Conyza bonariensis*) control at 14 days after treatment (DAT) with doses of 2,4-D alone or mixed with quizalofop-P-tefuryl (fop) and/or adjuvant (adj.).

Herbicides	2,4-D (g a.e. ha^{-1})	Control (%)	
		Without adj.	With adj.
2,4-D	0	0 Ba	5 Aa
	125.62	13 Aa	13 Aa
	251.25	15 Ba	21 Aa
	502.5	23 Aa	26 Aa
	1,005	31 Aa	31 Ab
	2,010	35 Aa	38 Ab
	4,020	38 Bb	68 Aa
2,4-D + fop	0	0 Ba	8 Aa
	125.62	5 Bb	11 Aa
	251.25	6 Bb	20 Aa
	502.5	11 Bb	23 Aa
	1,005	21 Bb	56 Aa
	2,010	28 Bb	65 Aa
	4,020	63 Aa	63 Aa

Means followed by different capital letters on the line indicate a significant difference for the adjuvant effect by Tukey's test ($p < 0.05$). Means followed by different lowercase letters within the same 2,4-D adjuvant dose level indicate a significant difference for the quizalofop-P-tefuryl factor by Tukey's test ($p < 0.05$).

At 21 DAT, as in the previous evaluation, the addition of quizalofop-P-tefuryl resulted in lower efficacy of the 2,4-D herbicide in the absence of adjuvant (Figure 1B and Table 2). However, in this evaluation, the reduction in hairy fleabane control with the addition of graminicide was observed only at doses of 2,4-D equal to or less than 502.5 g a.e. ha^{-1}. At doses above recommended, the addition of quizalofop-P-tefuryl did not reduce the efficacy of 2,4-D.

Adjuvant addition resulted in better efficacy of 2,4-D, regardless of the presence or absence of quizalofop-P-tefuryl (Figure 1B and Table 2). This positive response to the addition of adjuvant was observed at all evaluated doses of 2,4-D. When considering the recommended dose (1,005 g a.e. ha^{-1}), the addition of adjuvant to 2,4-D resulted in 86% control, 16% superior to treatment without adjuvant. A similar result was obtained when the graminicide was added to the spray solution, with an increase of 12% in the control of hairy fleabane with the addition of adjuvant.

Tabela 2. Unfolding of the interaction of evaluated factors on hairy fleabane (Conyza bonariensis) control at 21 days after treatment (DAT) with doses of 2,4-D alone or mixed with quizalofop-P-tefuryl (fop) and/or adjuvant (adj.).

Herbicides	2,4-D (g a.e. ha^{-1})	Control (%)	
		Without adj.	With adj.
2,4-D	0	0 Bb	10 Aa
	125.62	30 Ba	41 Ab
	251.25	38 Ba	59 Aa
	502.5	61 Ba	67 Aa
	1,005	70 Ba	86 Aa
	2,010	73 Ba	91 Aa
	4,020	81 Ba	95 Aa
2,4-D + fop	0	9 Aa	11 Aa
	125.62	20 Bb	54 Aa
	251.25	30 Bb	65 Aa
	502.5	46 Bb	72 Aa
	1,005	64 Ba	86 Aa
	2,010	71 Ba	86 Aa
	4,020	88 Aa	82 Ab

Means followed by different capital letters on the line indicate a significant difference for the adjuvant effect by Tukey's test ($p < 0.05$). Means followed by different lowercase letters within the same 2,4-D adjuvant dose level indicate a significant difference for the quizalofop-P-tefuryl factor by Tukey's test ($p < 0.05$).

The results obtained at 28 DAT are similar to those observed in the previous evaluation in relation to the addition of quizalofop-P-tefuryl, that is, at 2,4-D doses equal to or less than 520.5 g a.e. ha^{-1} the control was reduced by 10 to 25% in the absence of adjuvant (Figure 1C and Table 3). However, at doses of 2,4-D from 1,005 g ha^{-1}, the addition of quizalofop-P-tefuryl did not result in a reduction in hairy fleabane control.

Tabela 3. Unfolding of the interaction of evaluated factors on hairy fleabane (Conyza bonariensis) control at 28 days after treatment (DAT) with doses of 2,4-D alone or mixed with quizalofop-P-tefuryl (fop) and/or adjuvant (adj.).

Herbicides	2,4-D (g a.e. ha^{-1})	Control (%)	
		Without adj.	With adj.
2,4-D	0	0 Bb	18 Aa
	125.62	45 Ba	63 Aa
	251.25	60 Ba	75 Aa
	502.5	68 Ba	78 Aa
	1,005	79 Ba	91 Aa
	2,010	88 Aa	95 Aa
	4,020	93 Aa	99 Aa
2,4-D + fop	0	9 Aa	10 Ab
	125.62	21 Bb	68 Aa
	251.25	40 Bb	78 Aa
	502.5	58 Bb	83 Aa
	1,005	76 Ba	96 Aa
	2,010	85 Aa	90 Aa
	4,020	99 Aa	91 Aa

Means followed by different capital letters on the line indicate a significant difference for the adjuvant effect by Tukey's test ($p < 0.05$). Means followed by different lowercase letters within the same 2,4-D adjuvant dose level indicate a significant difference for the quizalofop-P-tefuryl factor by Tukey's test ($p < 0.05$).

In treatments with addition of adjuvant, the addition of quizalofop-P-tefuryl had no effect on the efficacy of 2,4-D, regardless of the dose of auxinic herbicide (Figure 1C and Table 3). Furthermore, the addition of adjuvant resulted in increased efficacy of 2,4-D at doses up to 1,005 g a.e. ha^{-1}. At this dose, hairy fleabane control was only 79% when the herbicide was applied without adjuvant. However, with the addition of adjuvant, the control was raised to 91%, resulting in a 12% increase in efficacy.

In the final evaluation, performed at 35 DAT, the addition of quizalofop-P-tefuryl resulted in a reduction in the efficacy of 2,4-D only at the lowest 2,4-D dose evaluated (125.62 g a.e. ha^{-1}) when the application was performed without adjuvant (Figure 1D and Table 4). Therefore, in this evaluation, at doses of 2,4-D from 251.25 g a.e. ha^{-1}, the addition of graminicide did not result in a significant reduction in the efficacy of 2,4-D in controlling hairy fleabane.

Table 4. Unfolding of the interaction of evaluated factors on hairy fleabane (Conyza bonariensis) control at 35 days after treatment (DAT) with doses of 2,4-D alone or mixed with quizalofop-P-tefuryl (fop) and/or adjuvant (adj.).

Herbicides	2,4-D (g a.e. ha^{-1})	Control (%)	
		Without adj.	With adj.
2,4-D	0	0 Bb	18 Aa
	125.62	50 Ba	67 Aa
	251.25	67 Ba	77 Aa
	502.5	75 Ba	80 Aa
	1,005	95 Aa	99 Aa
	2,010	93 Aa	100 Aa
	4,020	100 Aa	100 Aa
2,4-D + fop	0	9 Aa	10 Ab
	125.62	23 Bb	65 Aa
	251.25	59 Ba	80 Aa
	502.5	66 Ba	84 Aa
	1,005	85 Aa	96 Aa
	2,010	89 Aa	95 Aa
	4,020	100 Aa	97 Aa

Means followed by different capital letters on the line indicate a significant difference for the adjuvant effect by Tukey's test ($p < 0.05$). Means followed by different lowercase letters within the same 2,4-D adjuvant dose level indicate a significant difference for the quizalofop-P-tefuryl factor by Tukey's test ($p < 0.05$).

Adjuvant addition resulted in better efficacy of 2,4-D doses below the recommended, regardless of the addition of quizalofop-P-tefuryl (Figure 1D and Table 4). For 2,4-D doses equal to or less than 502.5 g a.e. ha^{-1}, the addition of adjuvant increased the control from 10% to 42%, with the greatest increases in the presence of quizalofop-P-tefuryl. At doses from 1,005 g a.e. ha^{-1}, the addition of adjuvant was not necessary for the control of hairy fleabane to be satisfactory (above 90%).

The lower efficacy observed at 35 DAT with the addition of quizalofop-P-tefuryl to low doses of 2,4-D resulted in a higher C^{50} value compared to the isolated application of 2,4-D, indicating a reduction in the control of hairy fleabane and the occurrence of antagonism (Table 5). The C_{50} of 2,4-D for the dose-response curve formed only by 2,4-D was 139.96 g a.e. ha^{-1}, and 249.23 g a.e. ha^{-1} when quizalofop-P-tefuryl was added. However, the addition of adjuvant resulted in a significant reduction in C_{50} for both situations, that is, the adjuvant compensated for the negative effect of graminicide on the efficacy of 2,4-D in controlling hairy fleabane. The C_{50} of 2,4-D for the dose-response curve formed by 2,4-D + adjuvant was 63.35 g a.e. ha^{-1}, and 75.89 g a.e. ha^{-1} when quizalofop-P-tefuryl was added to 2,4-D + adjuvant.

Table 5. C_{50} values for the variable hairy fleabane control at 35 days after application of treatments (DAT).

Treatments	C_{50} (g a.e. 2,4-D ha^{-1})
2,4-D	139.96 (± 22.80)
2, 4-D + adjuvant	63.35 (±23.43)
2,4-D + quizalofop-P-tefuryl	249.23 (±58.86)
2, 4-D + adjuvant + quizalofop-P-tefuryl	75.89 (± 16.99)

C_{50}: dose of 2,4-D that promotes 50% of control.

For the variable SDM, the addition of quizalofop-P-tefuryl had no significant effect (Figure 2 and Table 6). However, the addition of adjuvant to 2,4-D resulted in a significant reduction in SDM for most auxinic herbicide doses, except for 502.5 and 4,020 g a.e. ha^{-1} (Table 6). At the recommended dose of 2,4-D (1,005 g a.e. ha^{-1}), the reduction in SDM compared to the control treatment was 53.3% when the application was performed without adjuvant, and 64.14% when performed with adjuvant.

Figure 2. Relative shoot dry mass (SDM) of hairy fleabane at 35 days after treatment (DAT) in response to the application of doses of 2,4-D alone or mixed with adjuvant (adj.).

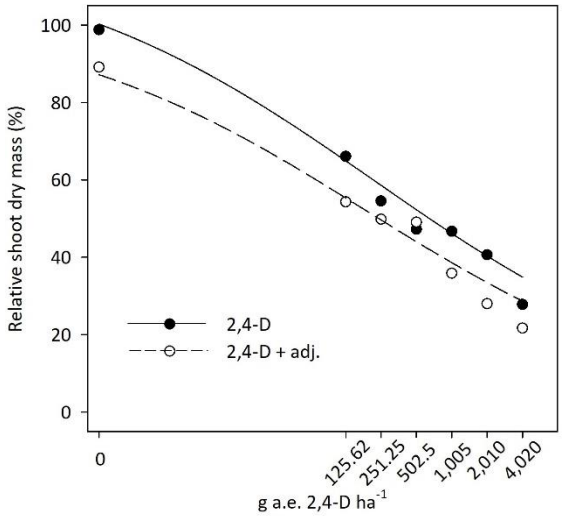

Table 6. Unfolding of the interaction of evaluated factors on hairy fleabane (*Conyza bonariensis*) relative shoot dry mass (SDM) at 35 days after treatment (DAT) in response to doses of 2,4-D in association or not with adjuvant (adj.).

2,4-D (g a.e. ha^{-1})	Relative SDM (%)	
	Without adj.	With adj.
0	99 A	89 B
125.62	66 A	54 B
251.25	55 A	50 B
502.5	47 A	49 A
1,005	47 A	36 B
2,010	41 A	28 B
4,020	28 A	22 A

Means followed by different capital letters on the line indicate a significant difference for the adjuvant effect by Tukey's test ($p < 0.05$).

4 DISCUSSION

The antagonism of auxinic herbicides on the effectiveness of ACCase-inhibiting herbicides in the control of poaceae is already well known, with results showing that the addition of 2,4-D to gramincides reduces the control of species such as ryegrass and sourgrass (Trezzi et al. 2007; Gomes et al. 2020). However, the reciprocity of this antagonism in eudicotyledonous weeds such as hairy fleabane is not reported in the literature. Our results demonstrate that the addition of quizalofop-P-

tefuryil reduced the efficacy of 2,4-D in treatments with low doses of auxinic herbicide and no adjuvant. At recommended doses of 2,4-D or with the addition of adjuvant, the inclusion of fluazifop-P-tefuryl did not result in a reduction in hairy fleabane control (Figure 1D and Table 4).

The occurrence of reciprocal antagonism between aryloxyphenoxypropanoates and auxinic herbicides has already been reported, but in trials carried out with root tissue culture (Shimakuburo et al. 1986). The authors observed that the addition of diclofop-methyl to 2,4-D inhibited the damage caused by the auxinic herbicide in soybean roots, just as the addition of 2,4-D to diclofop-methyl prevented the damage caused by the graminicide. in corn roots. Later, in another experiment, the same research group observed that the reciprocity of antagonism occurs as a function of the transmembrane gradient of protons (Shimakuburo et al. 1989). Auxins, such as 2,4-D, have several functions, including maintaining the electrical potential of membranes. On the other hand, ACCase-inhibiting graminicides, in addition to inhibiting lipid synthesis, act as anti-auxins, changing the electrical gradient of membranes, resulting in antagonism (Cobb and Reade 2010).

In addition to the effect of adding fluazifop-P-teduryl, the effect of adding an ethoxylated alkyl ester phosphoric acid adjuvant to the spray solution was evaluated. Adjuvant addition improved the efficacy of 2,4-D in the final control (at 35 DAT) of hairy fleabane only at doses below the recommended (Figure 1D and table 4). In other words, at doses of 2,4-D from 1,005 g a.e. ha^{-1}, the addition of adjuvant to the spray solution did not result in an increase in control. Similar results were obtained by Soares et al. (2012), in which the authors observed control greater than 90% with the application of the recommended dose of 2,4-D in hairy fleabane plants with 10 to 12 leaves. Likewise, but in smaller plants (with 4 leaves), Vargas et al. (2007) obtained 95% control with the application of 1,005 g a.e. ha^{-1} of 2,4-D. In both experiments, the authors did not report the use of adjuvant together with 2,4-D. Both the results of the literature mentioned above and those of the present research are in accordance with the manufacturer's recommendation (Agrofit 2021). It is only recommended to use an adjuvant of the adhesive spreading type mixed with 2,4-D for the control of purple nutsedge (*Cyperus rotundus*) in the sugarcane crop.

It is important to emphasize that the addition of adjuvant to the spray solution provided control over 80% in doses of 2,4-D from 251.25 g a.e. ha^{-1} (Figure 1D and Table 4). However, without the addition of 2,4-D, these same control indices were obtained from the recommended dose. Thus, although not recommended, the addition of adjuvant allowed a reduction in the applied dose without compromising the performance of the 2,4-D herbicide in controlling hairy fleabane with up to 12 leaves. At low doses of 2,4-D, it is believed that the addition of adjuvant improves the absorption of the herbicide, improving its effectiveness, even with a low concentration.

Adjuvants are responsible for breaking the surface tension of the water used in the spray solution, increasing the contact area of the drop with the leaf surface (Montório et al. 2010). In addition, adjuvants promote the loosening of epicuticular waxes, creating pathways that allow greater herbicide absorption (Tan et al. 1994; Thompson et al. 1996). Studies carried out in bean plants have shown that both the absorption and translocation of ^{14}C-2,4-D were increased with the addition of adjuvant of the same nature (non-ionic ethylene oxides) and at the same concentration (0.5% v/ v) that used in this study (Holloway and Edgeton 1992).

5 CONCLUSIONS

The addition of fluazifop-P-tefuryl to 2,4-D results in antagonism in the control of 12-leaf horseweed only when 2,4-D is applied at doses lower than recommended (less than 1,005 g a.e. ha^{-1}).

The addition of phosphoric acid ethoxylated alkyl ester adjuvant improves the efficacy of 2,4-D in the control of hairy fleabane, offsetting the negative effect caused by the addition of quizalofop-P-tefuryl. However, at doses of 2,4-D from the recommendation (1,005 g a.e. ha^{-1}), the addition of adjuvant is not necessary for the control of hairy fleabane with up to 12 leaves.

Therefore, the antagonism between quizalofop-P-tefuryl and 2,4-D is reciprocal, but it depends on the dose of 2,4-D and the absence of adjuvant to the application solution.

As future research, it is suggested that other experiments be carried out, considering other herbicides that inhibit ACCase and other auxin mimics. Variations in results may occur with other herbicides, as well as other adjuvants. Furthermore, there is a need to carry out studies with other important weed species, in addition to *Conyza bonariensis*.

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