Mixtures between glyphosate formulations and ACCase-inhibiting herbicides in the control of *Chloris elata*

Mezclas de formulaciones de glifosato y herbicidas inhibidores de ACCase em el control de *Chloris elata*

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Originales: *Recepción:* 10/10/2019 - *Aceptación:* 15/07/2020

Abstract

Chloris elata is an important weed for grain and sugarcane crops. In addition to its aggressiveness, it may show resistance to glyphosate herbicide. In this context, the aim of this study was to assess the effectiveness of glyphosate formulations, isolated or in association with ACCase inhibitors, in controlling *C. elata* (putatively resistant to glyphosate) at different developmental stages. Four experiments were conducted in a completely randomized design. Treatments consisted of glyphosate application under different formulations with ACCase inhibitors, isolated or in mixtures. Applications were carried out at the stages of four fully expanded leaves in Experiment I, four tillers in Experiment II, and at regrowth of the four-tiller plants in Experiments III and IV. Applications of glyphosate isopropylamine salt associated with sethoxydim or clethodim showed to be among the best treatments in Experiments I, II, and III, presenting control scores equal to or greater than 90%. However, not even these treatments could provide successful control in Experiment IV. Moreover, and regardless of the formulation, isolated glyphosate, showed 85% (Experiment III) and 50% (Experiment IV) maximum controls. Associations between glyphosate and ACCase-inhibiting herbicides showed to be effective in controlling *C. elata*, especially at early developmental stages. In general, isolated herbicides provided lower percentages of control, as well as higher values of dry matter. Sole herbicide applications were not effective in controlling *C. elata* (putatively resistant to glyphosate), regardless of the developmental stage.

Keywords
chemical control • clethodim • haloxyfop • quizalofop • sethoxydim • tank mix

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Resumen

Chloris elata es una maleza importante para cultivos de cereales y caña de azúcar. Además de su agresividad, presenta casos de resistencia al herbicida glifosato. El objetivo de este estudio fue evaluar la efectividad de formulaciones de glifosato, solas o en mezclas con inhibidores de la ACCase, en el control de *C. elata* (supuestamente resistente al glifosato) en diferentes estadios. Se realizaron cuatro experimentos en un diseño completamente al azar. Los tratamientos consistieron en la aplicación de glifosato en diferentes formulaciones con inhibidores de ACCase, solo o en mezclas. Las aplicaciones de los tratamientos se llevaron a cabo en las etapas de cuatro hojas completamente expandidas en el Experimento I y cuatro macollos en el Experimento II, y en el rebrote de las plantas de cuatro macollos en los Experimentos III y IV. La aplicación de glifosato sal de isopropilamina, en mezclas con setoxidim o cletodim, siempre estuvo entre los mejores tratamientos en los Experimentos I, II y III, presentó puntuaciones de control iguales o superiores a 90%. Sin embargo, incluso estos tratamientos no proporcionaron un control satisfactorio en el Experimento IV. En general, los herbicidas solos proporcionaron porcentajes de control más bajos, así como valores más altos de materia seca. Además, el herbicida de glifosato solo, independientemente de la formulación, mostró 85% (Experimento III) y 50% (Experimento IV) de controles máximos. Las mezclas entre glifosato y los herbicidas inhibidores de la ACCase demostraron ser efectivas en el control de *C. elata*, especialmente en estadios iniciales. En general, las aplicaciones solas de herbicidas no fueron efectivas para controlar *C. elata* (supuestamente resistente al glifosato), independientemente del estadio.

Palabras clave
control químico • cletodim • haloxifop • quizalofop • setoxidim • mezcla de tanque

Introduction

Species of the genus *Chloris,* family Poaceae, presents annual or perennial plants of C4 physiology with well-developed Kranz anatomy and a high adaptive capacity to different habitats (17, 21). The species *Chloris elata* (Syn.: *Chloris polydactyla,* native to America, presents seed and/or rhizome reproduction (11, 17). One single plant can produce more than 96,000 seeds (8).

Populations of *C. elata* present cases of glyphosate resistance (4, 6, 9). Other species of this genus, such as *C. barbata* (7), *C. virgata* (20), *C. truncata* (19), and *C. distichophylla* (30) are also reported as resistant. In the last years, these species have gained importance in different crops, mainly grains and sugarcane, thus increasing the number of studies on their biology and management (2, 3, 9, 12, 13, 25). In addition, no specific recommendations of glyphosate as chemical control of *C. elata* are available (4). Rotational mechanisms of action and herbicide associations have significant importance in the management of hard-to-control weeds, as well as in the prevention of herbicide-resistant biotypes selection (16). Thus, the hypothesis is that glyphosate and ACCase-inhibiting mixture effectively controls *C. elata* in different stages of development. Therefore, this study aimed to assess the effectiveness of glyphosate formulations with ACCase-inhibiting herbicides, against *C. elata* (putatively resistant to glyphosate) at different development stages.

Materials and methods

Greenhouse experiments

The experiments were conducted in a greenhouse, from November to December 2014, located in the Department of Crop Science of the University of São Paulo, "Luiz de Queiroz" College of Agriculture (USP/ESALQ), Piracicaba, State of São Paulo (SP), Brazil. During the conduction period of the study, an average temperature of 25.3°C and 13 h daylight^{-1} was observed.

Seeds of *C. elata* population identified with a possible resistance were collected according to Burgos *et al*. (2013) from a citrus area located in Matão, SP, Brazil (21.61°S, 48.44°W), with a history of repetitive glyphosate applications. Seeds from this collection were sown in pots filled in a 1:1 ratio of substrate and medium-textured soil with the characteristics described in table 1.

Table 1. Chemical and physical soil analysis.

Tabla 1. Análisis químico y físico del suelo.

pH	P	K	Ca	Mg	H + Al	SB	CEC	V	Clay	Silt	Sand
6.2	5.0	4.2	41.0	15.0	< 26.0	60.1	72.5	83.0	276	86	638

Unities: H + Al, K, Ca, Mg, SB (sum of bases), and CEC (cation exchange capacity): $mmol_c\ dm^{-3}$; P: $mg\ dm^{-3}$; V (base saturation): %; clay, silt, and sand: $g\ Kg^{-1}$.

Unidades: H + Al, K, Ca, Mg, SB (suma de bases), and CEC (capacidad de intercambiar cationes): $mmol_c\ dm^{-3}$; P: $mg\ dm^{-3}$; V (saturación de bases): %; arcilla, limo y arena: $g\ Kg^{-1}$.

Four experiments were conducted in a completely randomized design with 19 herbicide treatments and a control without application (table 2). Treatment applications were carried out at the stages of four fully expanded leaves in Experiment I and four tillers in Experiment II. In both experiments, four replications were used per treatment in 5 L pots. For Experiments III and IV, the applications were conducted in the regrowth of the four-tiller plants, with three replications per treatment in 5 L (Experiment III) and 7 L pots (Experiment IV).

Table 2. Treatments for control of *C. elata* with different formulations of glyphosate and ACCase inhibitors, alone and in mixtures.

Tabla 2. Tratamientos para el control de *C. elata* con diferentes formulaciones de glifosato e inhibidores de ACCase, solas o en mezcla.

Treatments [1]	Rate [2]	
	Exp. I	Exp. II. III and IV
1. glyphosate IS	720	720
2. glyphosate IS + quizalofop	720 + 60	720 + 120
3. glyphosate IS + haloxyfop	720 + 48	720 + 60
4. glyphosate IS + sethoxydim	720 + 184	720 + 368
5. glyphosate IS + clethodim	720 + 84	720 + 108
6. glyphosate AS	720	720
7. glyphosate AS + quizalofop	720 + 60	720 + 120
8. glyphosate AS + haloxyfop	720 + 48	720 + 60
9. glyphosate AS + sethoxydim	720 + 184	720 + 368
10. glyphosate AS + clethodim	720 + 84	720 + 108
11. glyphosate PS	720	720
12. glyphosate PS + quizalofop	720 + 60	720 + 120
13. glyphosate PS + haloxyfop	720 + 48	720 + 60
14. glyphosate PS + sethoxydim	720 + 184	720 + 368
15. glyphosate PS + clethodim	720 + 84	720 + 108
16. quizalofop	60	120
17. haloxyfop	48	60
18. sethoxydim	184	368
19. clethodim	84	108
20. control (without application)	-	-

[1] Commercial products: Roundup Ready® - glyphosate IS (isopropylamine salt); Roundup® WG - glyphosate AS (ammonium salt); Zapp® QI 620 - glyphosate PS (potassium salt); Panther® 120 EC - quizalofop; Verdict® R - haloxyfop; Poast® - sethoxydim; Select® 240 EC - clethodim. For quizalofop and sethoxydim applications it was used adjuvant Joint® Oil (2 L ha^{-1}); for haloxyfop, Joint® Oil (1 L ha^{-1}); for clethodim, Lanzar® (1 L ha^{-1}). [2] Rates in grams of acid equivalent (g a.e. ha^{-1}) for glyphosate and haloxyfop, and grams of active ingredient (g a.i. ha^{-1}) for the other herbicides.

[1] Productos comerciales: Roundup Ready® - glifosato IS (sal de isopropilamina); Roundup® WG - glifosato AS (sal de amonio); Zapp® QI 620 - glifosato PS (sal de potasio); Panther® 120 EC - quizalofop; Verdict® R - haloxifop; Poast® - setoxidim; Select® 240 EC - cletodim. Para las aplicaciones de quizalofop y setoxidim se utilizó adyuvante Joint® Oil (2 L ha^{-1}); para haloxifop, Joint® Oil (1 L ha^{-1}); for cletodim, Lanzar® (1 L ha^{-1}). [2] Dosis en gramos de equivalente de ácido (g e.a. ha^{-1}) para glifosato y haloxifop, y gramos de ingrediente activo (g i.a. ha^{-1}) para los otros herbicidas.

Treatment applications were carried out in an experimental herbicide spraying chamber, powered by an electric motor, with a constant pressure of 40 psi, and equipped with spray tips flat-fan Teejet® 8002 positioned at 50 cm from the target and with a spray solution volume of 200 L ha^{-1}.

Data gathering

The control of *C. elata* was assessed for each treatment at 7, 14, 21, and 28 days after application (DAA) through visual assessments in which percentage scores ranging from 0 to 100% were assigned to each experimental unit, where 0 represents no injury and 100% represents plant death (31).

At 28 DAA, the aerial part of each plant was collected to determine the dry matter by using a forced air ventilation oven at 65 °C for 72 h and an analytical balance with accuracy to three decimal places.

Statistical analyses

The data were submitted to analysis of variance by F-test ($P < 0.01$), while the means of treatments were compared by the Scott and Knott (1974) test ($P < 0.01$) (24).

Results

Experiment I

At 7 DAA, some differences were observed in *C. elata* control. However, with absolute values not exceeding 16.25%. At 14 DAA, the application of glyphosate isopropylamine salt (IS) + clethodim provided a control of 81.25%, which was higher than those observed in all other treatments. At 21 DAA, greater control results were observed for the application of glyphosate IS + clethodim, glyphosate IS + haloxyfop, glyphosate IS + sethoxydim, and glyphosate potassium salt (PS) + clethodim, with control scores higher than 85%, which was higher than those observed in all other treatments. Similarly, it was observed at 28 DAA, with control scores equal to or greater than 90%. All treatments presented a reduction in *C. elata* dry matter in relation to the control (without application). While the application of glyphosate IS reduced the *C. elata* dry matter only in relation to the control, presenting values superior to all other treatments (table 3, page 278).

Experiment II

At 7 DAA, some differences were observed in *C. elata* control. However, control percentages were low, with absolute values not exceeding 18.75%. At 14 DAA, the application of glyphosate IS + sethoxydim provided a control of 83.75%, which was higher than those observed in all other treatments. At 21 DAA, the best control results were observed for the application of glyphosate IS + sethoxydim, glyphosate ammonium salt (AS) + quizalofop, glyphosate AS + sethoxydim, and glyphosate AS + clethodim, with control scores equal to or greater than 86.25%, which was higher than those observed in all other treatments.

At 28 DAA, greater control results were observed for the application of glyphosate IS + sethoxydim, glyphosate IS + clethodim, glyphosate AS in association with any of the graminicides, glyphosate PS + haloxyfop, glyphosate PS + sethoxydim, and glyphosate PS + clethodim, with control scores equal to or greater than 87.50%, which was higher than those observed in all other treatments. In addition, all treatments showed a reduced dry matter value in relation to the control, and no differences were observed between herbicide treatments (table 4, page 278).

Table 3. Control (%) at 7, 14, 21 and 28 DAA, and dry matter (mg) of *C. elata* (Exp. I).
Tabla 3. Control (%) a 7, 14, 21 y 28 DAA, y materia seca (mg) de *C. elata* (Exp. I).

Treatments[1]	Control (DAA)				Dry mass
	7	14	21	28	
1. glyphosate IS	11.25 a	56.25 d	76.25 c	81.25 c	165.00 c
2. glyphosate IS + quizalofop	12.50 a	58.75 d	82.50 b	87.50 b	133.25 a
3. glyphosate IS + haloxyfop	12.50 a	70.00 c	88.75 a	92.50 a	105.00 a
4. glyphosate IS + sethoxydim	11.25 a	67.50 c	86.25 a	91.25 a	115.00 a
5. glyphosate IS + clethodim	12.50 a	81.25 a	88.75 a	93.75 a	85.00 a
6. glyphosate AS	12.50 a	65.00 c	72.50 c	81.25 c	136.50 b
7. glyphosate AS + quizalofop	16.25 a	72.50 b	81.25 b	87.50 b	102.50 a
8. glyphosate AS + haloxyfop	12.50 a	71.25 c	81.25 b	86.25 b	120.00 b
9. glyphosate AS + sethoxydim	13.75 a	67.50 c	78.75 b	83.75 b	95.00 a
10. glyphosate AS + clethodim	12.50 a	67.50 c	80.00 b	86.25 b	96.50 a
11. glyphosate PS	8.75 a	60.00 d	72.50 c	77.50 c	103.25 a
12. glyphosate PS + quizalofop	12.50 a	56.25 d	73.75 c	80.00 c	117.50 b
13. glyphosate PS + haloxyfop	10.00 b	66.25 c	75.00 c	82.50 c	120.00 b
14. glyphosate PS + sethoxydim	12.50 a	67.50 c	81.25 b	85.00 b	103.25 a
15. glyphosate PS + clethodim	10.00 b	73.75 b	85.00 a	90.00 a	102.50 a
16. quizalofop	10.00 b	55.00 d	70.00 c	77.50 c	106.50 a
17. haloxyfop	5.00 b	53.75 d	70.00 c	78.75 c	115.00 a
18. sethoxydim	7.50 b	52.50 d	65.00 d	71.25 c	122.50 b
19. clethodim	6.25 b	48.75 d	62.50 d	75.00 c	130.00 b
20. control (without application)	0.00 c	0.00 e	0.00 e	0.00 d	270.00 d
CV (%)	25.23	7.55	7.03	6.02	13.64
F	7.44**	52.25**	52.89**	67.43**	22.15**
P>F	0.00	0.00	0.00	0.00	0.00

[1] IS (isopropylamine salt); AS (ammonium salt); PS (potassium salt). ** Means followed by the same letter in the column did not differ between the Scott and Knott (1974) test ($P < 0.01$).
[1] IS (sal de isopropilamina); AS (sal de amonio); PS (sal de potasio). ** Los medios seguidos por la misma letra en la columna no difirieron por el teste de Scott y Knott (1974) ($P < 0,01$).

Table 4. Control (%) at 7, 14, 21 and 28 DAA, and dry matter (mg) of *C. elata* (Exp. II).
Tabla 4. Control (%) a 7, 14, 21 y 28 DAA, y materia seca (mg) de *C. elata* (Exp. II).

Treatments[1]	Control (DAA)				Dry mass
	7	14	21	28	
1. glyphosate IS	8.75 b	55.00 d	66.25 c	81.25 b	180.00 a
2. glyphosate IS + quizalofop	11.25 b	58.75 d	76.25 c	85.00 b	162.50 a
3. glyphosate IS + haloxyfop	12.50 b	65.00 c	80.00 b	86.25 b	162.50 a
4. glyphosate IS + sethoxydim	18.75 a	83.75 a	91.25 a	95.00 a	150.00 a
5. glyphosate IS + clethodim	16.25 a	70.00 b	83.75 b	91.25 a	160.00 a
6. glyphosate AS	10.00 b	62.50 c	71.25 c	80.00 b	210.00 a
7. glyphosate AS + quizalofop	15.00 a	67.50 c	88.75 a	92.50 a	180.00 a
8. glyphosate AS + haloxyfop	12.50 b	66.25 c	80.00 b	88.75 a	195.00 a
9. glyphosate AS + sethoxydim	13.75 a	76.25 b	87.50 a	92.50 a	185.75 a
10. glyphosate AS + clethodim	13.75 a	70.00 b	86.25 a	92.50 a	205.00 a
11. glyphosate PS	8.75 b	56.25 d	72.50 c	78.75 b	210.00 a
12. glyphosate PS + quizalofop	13.75 a	62.50 c	76.25 c	86.25 b	195.00 a
13. glyphosate PS + haloxyfop	12.50 b	60.00 d	78.75 c	87.50 a	195.00 a
14. glyphosate PS + sethoxydim	17.50 a	63.75 c	81.25 b	90.00 a	190.00 a
15. glyphosate PS + clethodim	15.00 a	62.50 c	75.00 c	87.50 a	206.50 a
16. quizalofop	13.75 a	62.50 c	73.75 c	81.25 b	206.50 a
17. haloxyfop	11.25 b	57.50 d	75.00 c	80.00 b	205.00 a
18. sethoxydim	15.00 a	65.00 c	73.75 c	85.00 b	210.00 a
19. clethodim	11.25 b	60.00 d	73.75 c	82.50 b	203.25 a
20. control (without application)	0.00 c	0.00 e	0.00 d	0.00 c	548.75 b
CV (%)	20.43	7.78	7.16	6.40	13.45
F	9.54**	44.74**	49.04**	57.44**	34.67**
P>F	0.00	0.00	0.00	0.00	0.00

[1] IS (isopropylamine salt); AS (ammonium salt); PS (potassium salt).** Means followed by the same letter in the column did not differ between the Scott and Knott (1974) test ($P < 0.01$).
[1] IS (sal de isopropilamina); AS (sal de amonio); PS (sal de potasio). ** Los medios seguidos por la misma letra en la columna no difirieron por el teste de Scott y Knott (1974) ($P < 0,01$).

Experiment III

Control scores equal to or greater than 81.67% were observed at 7 DAA for the treatments with glyphosate IS + clethodim, glyphosate AS + haloxyfop, glyphosate AS + sethoxydim, glyphosate PS + haloxyfop, glyphosate PS + clethodim, with values higher than those observed in all other treatments. In the subsequent assessments, all herbicide treatments showed control scores higher than 75%, except for the application of haloxyfop, which provided a control of 63.33% at the 14 DAA. At 28 DAA, all herbicide treatments showed control scores higher than 83%. For dry matter, no differences were observed between herbicide treatments, with lower values in relation to the control (table 5).

Table 5. Control (%) at 7, 14, 21 and 28 DAA, and dry matter (mg) of *C. elata* (Exp. III).
Tabla 5. Control (%) a 7, 14, 21 y 28 DAA, y materia seca (mg) de *C. elata* (Exp. III).

Treatments[1]	Control (DAA)				Dry mass
	7	14	21	28	
1. glyphosate IS	68.33 c	76.33 b	81.67 c	85.00 b	205.00 a
2. glyphosate IS + quizalofop	63.33 c	78.33 b	86.67 b	88.33 b	195.00 a
3. glyphosate IS + haloxyfop	75.00 b	88.33 a	91.67 a	94.33 a	168.33 a
4. glyphosate IS + sethoxydim	78.33 b	88.33 a	91.67 a	91.67 a	185.00 a
5. glyphosate IS + clethodim	81.67 a	86.67 a	91.67 a	94.33 a	180.00 a
6. glyphosate AS	68.33 c	76.33 b	80.00 c	83.33 b	205.00 a
7. glyphosate AS + quizalofop	65.00 c	76.67 b	86.67 b	91.67 a	202.33 a
8. glyphosate AS + haloxyfop	85.00 a	88.33 a	88.33 b	94.33 a	180.00 a
9. glyphosate AS + sethoxydim	83.33 a	91.67 a	95.00 a	96.00 a	175.00 a
10. glyphosate AS + clethodim	78.33 b	81.67 a	88.33 b	94.33 a	185.00 a
11. glyphosate PS	68.33 c	75.00 b	78.33 c	83.33 b	205.00 a
12. glyphosate PS + quizalofop	78.33 b	81.67 a	83.33 c	86.67 b	195.00 a
13. glyphosate PS + haloxyfop	83.33 a	86.67 a	91.67 a	94.33 a	187.33 a
14. glyphosate PS + sethoxydim	78.33 b	88.33 a	93.33 a	94.33 a	175.00 a
15. glyphosate PS + clethodim	83.33 a	91.67 a	95.00 a	96.00 a	160.00 a
16. quizalofop	73.33 b	80.00 b	83.33 c	85.00 b	205.00 a
17. haloxyfop	55.00 d	63.33 c	76.67 c	83.33 b	202.86 a
18. sethoxydim	73.33 b	85.00 a	86.67 b	88.33 b	198.14 a
19. clethodim	70.00 c	76.67 b	80.00 c	86.67 b	195.43 a
20. control (without application)	0.00 e	0.00 d	0.00 d	0.00 c	480.71 b
CV (%)	6.11	4.92	4.39	4.62	16.30
F	54.55**	79.60**	93.57**	81.81**	22.81**
P>F	0.00	0.00	0.00	0.00	0.00

[1] IS (isopropylamine salt); AS (ammonium salt); PS (potassium salt). ** Means followed by the same letter in the column did not differ between the Scott and Knott (1974) test ($P < 0.01$).

[1] IS (sal de isopropilamina); AS (sal de amonio); PS (sal de potasio). ** Los medios seguidos por la misma letra en la columna no difirieron por el teste de Scott y Knott (1974) ($P < 0,01$).

Experiment IV

Greater control results of *C. elata* at 28 DAA were observed in glyphosate applications (regardless of the formulation) associated with sethoxydim or clethodim and in glyphosate AS or PS with haloxyfop. However, control values did not exceed 68.33% (table 6, page 280). Isolated herbicide applications presented the worst control percentages, reaching a maximum of 51.67% for clethodim application at 28 DAA. Among all herbicide treatments, the lowest control values were observed for the isolated application of haloxyfop (38.33%) and quizalofop (33.33%). All herbicide treatments reduced plant dry matter when compared to the control. However, satisfactory controls of *C. elata* were not observed over the assessments.

Table 6. Control (%) at 7, 14, 21 and 28 DAA, and dry matter (mg) of *C. elata* (Exp. IV).
Tabla 6. Control (%) a 7, 14, 21 y 28 DAA, y materia seca (mg) de *C. elata* (Exp. IV).

Treatments[1]	Control				Dry mass
	7	14	21	28	
1. glyphosate IS	23.33 c	30.00 c	38.33 d	45.00 b	3466.67 b
2. glyphosate IS + quizalofop	25.00 c	35.00 c	43.33 c	50.00 b	3453.33 b
3. glyphosate IS + haloxyfop	38.33 b	46.67 b	53.33 b	58.33 b	3416.67 b
4. glyphosate IS + sethoxydim	48.33 a	61.67 a	65.00 a	68.33 a	2736.67 a
5. glyphosate IS + clethodim	43.33 b	53.33 b	61.67 a	66.67 a	2033.33 a
6. glyphosate AS	25.00 c	31.67 c	38.33 d	48.33 b	2740.00 a
7. glyphosate AS + quizalofop	28.33 c	35.00 c	45.00 c	51.67 b	2666.67 a
8. glyphosate AS + haloxyfop	53.33 a	56.67 a	65.00 a	68.33 a	1960.00 a
9. glyphosate AS + sethoxydim	48.33 a	56.67 a	61.67 a	68.33 a	2263.33 a
10. glyphosate AS + clethodim	46.67 a	51.67 b	58.33 a	66.67 a	2230.00 a
11. glyphosate PS	30.00 c	36.67 c	43.33 c	50.00 b	2596.67 a
12. glyphosate PS + quizalofop	31.67 c	40.00 c	46.67 c	55.00 b	2390.00 a
13. glyphosate PS + haloxyfop	40.00 b	46.67 b	58.33 a	68.33 a	2033.33 a
14. glyphosate PS + sethoxydim	40.00 b	50.00 b	56.67 a	68.33 a	2283.33 a
15. glyphosate PS + clethodim	51.67 a	58.33 a	60.00 a	65.00 a	1990.00 a
16. quizalofop	26.67 c	28.33 c	30.00 d	33.33 c	2770.00 a
17. haloxyfop	31.67 c	33.33 c	36.67 d	38.33 c	2546.67 a
18. sethoxydim	31.67 c	35.00 c	40.00 c	46.67 b	1936.67 a
19. clethodim	31.67 c	40.00 c	48.33 b	51.67 b	1856.67 a
20. control (without application)	0.00 d	0.00 d	0.00 e	0.00 d	4826.67 c
CV (%)	14.03	12.27	9.48	8.68	10.96
F	19.79**	23.74**	34.17**	38.76**	3.38**
P>F	0.00	0.00	0.00	0.00	0.00

[1] IS (isopropylamine salt); AS (ammonium salt); PS (potassium salt). ** Means followed by the same letter in the column did not differ between the Scott and Knott (1974) test ($P < 0.01$).

[1] IS (sal de isopropilamina); AS (sal de amonio); PS (sal de potasio). ** Los medios seguidos por la misma letra en la columna no difirieron por el teste de Scott y Knott (1974) ($P < 0,01$).

Discussion

In Experiments I, II, and III, the application of glyphosate IS associated with sethoxydim or clethodim stood out at 28 DAA, being always among the best treatments, with control scores equal to or greater than 90%. In this sense, haloxyfop was only inferior in Experiment II. However, even these treatments did not provide a satisfactory control in Experiment IV. These lower control percentages for Experiment IV can be explained using larger pots (7 L), which, in hypothesis, may have favored a greater root development of plants, leading to lower control percentages. In another study, this weed showed high growth as well as interference with soybean crop, when grown in 7 L pots (3). This possible greater root development, coupled with the fact that they are plants from regrowth, also helps to explain the higher values of dry matter, in relation to the control at 28 DAA.

In general, the isolated herbicides and associations presenting quizalofop provided lower control percentages. Moreover, the isolated glyphosate, regardless of the formulation, showed maximum controls of 85.00% for Experiment III and 50.00% for Experiment IV. Placido *et al*. (2016) observed a 100% control of *C. elata* biotypes when applying glyphosate IS (720 g a.e. ha^{-1}) + clethodim (108 g a.i. ha^{-1}). Nonemacher *et al*. (2017) verified a 97% control of *D. ciliaris* at 21 DAA in the application of glyphosate IS (1080 g a.e. ha^{-1}) + clethodim (96 g a.i. ha^{-1}). Mixtures of glyphosate PS (900 g a.e. ha^{-1}) with clethodim (60 g a.i. ha^{-1}) or sethoxydim (300 g a.i. ha^{-1}) were also effective in controlling volunteer maize, with percentages above 95%, but an association of this same glyphosate formulation with quizalofop (72 g a.i. ha^{-1}) was not effective (29). The results aforementioned reinforce the use of glyphosate and inhibitors of ACCase mixtures to effectively control *C. elata* and other grasses.

Nunes *et al*. (2007) observed a control of *C. distichophylla* equal to or greater than 85% for the application of glyphosate and fluazifop, but the clethodim application did not present a satisfactory control (10%), again with the most effective mixtures. The herbicides clodinafop (48 g a.i. ha^{-1}), haloxyfop (60 g a.e. ha^{-1}), clethodim (120 g a.i. ha^{-1}), fluazifop (187.5 g a.i. ha^{-1}),

tepraloxydim (100 g a.i. ha^{-1}), sethoxydim (221 g a.i. ha^{-1}), and quizalofop (60 g a.i. ha^{-1}) were effective in controlling *C. elata* of 20 cm in height and with six leaves. For flowering plants (85 cm in height), only glyphosate (1440 g a.e. ha^{-1}) provided a satisfactory control (8). These results suggest that the effectiveness of ACCase inhibitors may vary with the stage and development of *Chloris* spp.

As previously mentioned, seeds of the *C. elata* population identified with possible resistance were collected in an area with a history of more than 10 years of successive glyphosate applications. The species *C. elata* was reported as resistant to glyphosate (6, 9) and as having a differential susceptibility (3). Herbicide mixture has a great importance in the management of weeds difficult-to-control, as well as in the prevention of selection of herbicide-resistant biotypes (16, 18). The results of our study indicate the association of glyphosate with ACCase-inhibiting herbicides as an effective alternative in controlling *C. elata*, as also observed by other authors for *Chloris* spp., (15, 27), also highlighting the herbicide glufosinate (GS inhibitor) in these mixtures, which indicates that other mechanisms of action should be considered in the management of *Chloris* spp. (28).

Weed management to prevent the selection of herbicide-resistant biotypes should be preventive (1, 5, 14, 18), using the herbicide combination highlighted in this study, herbicide rotation of different mechanisms of action, groups of ACCase herbicides, and other management strategies beyond chemical control, such as those cultural, physical, and mechanical.

Conclusion

Mixtures between glyphosate and ACCase-inhibiting herbicides have been shown to be effective in controlling *C. elata*, especially in the early development stages. In general, isolated herbicide applications were not effective in controlling *C. elata* (putatively resistant to glyphosate), regardless of the development stage.

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