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RESEARCH ARTICLE

Use of herbicides to control regrowth plants of *Euphorbia heterophylla* (L.)

Uso de herbicidas para o controle de plantas rebrotadas de *Euphorbia heterophylla* (L.)

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Abstract: Background: The control of mature weeds in agriculture demands higher costs and more complex management strategies than the treatment of younger plants. This control is more difficult on regrowth weeds with morphologic, physiologic, and biochemical characteristics that provide higher tolerance.
Objective: This study aims to evaluate the control efficiency of different herbicides and associations, in different doses, on regrowth plants of *Euphorbia heterophylla* (L.) after the cultivation of common beans in a second harvest.
Methods: The experiment was conducted in the fall the 2020 under field conditions in a randomized block design with four replications of thirteen treatments: control (without herbicide); glyphosate (868 and 1736 g ha^{-1}); metsulfuron (1.2 and 2.4 g ha^{-1}); 2.4-D (335 and 670 g ha^{-1}); metsulfuron + 2.4-D (1.2 + 335 g ha^{-1} and 2.4 + 670 g ha^{-1}); iodosulfuron (1.75 and 3.5 g ha^{-1}); triclopyr (48 and 96 g ha^{-1}). Thirty-five days after the herbicide application, the following characteristics were evaluated: phytotoxicity, plant height, number of seeds per plant, and dry mass.
Results: The results demonstrate that the use of glyphosate in both doses tested provides adequate control of regrowth plants of *E. heterophylla*.
Conclusions: The use of metsulfuron + 2.4-D (2.4+670 g ha^{-1}) stands out as an efficient alternative to control *E. heterophylla* when it is not possible the use of full action herbicides, demonstrating high control efficacy (94%) and reduction of dry mass (89%).

Keywords: *E. heterophylla*, control efficiency, herbicide mixtures, fall management.

Resumo: Introdução: O controle de plantas daninhas adultas em lavouras demanda maior custo e estratégias de manejo mais complexas, quando comparadas a plantas jovens. Tal controle é ainda mais difícil sobre plantas rebrotadas, as quais apresentam características morfológicas, fisiológicas e bioquímicas que proporcionam maior tolerância.
Objetivo: O trabalho teve por objetivo avaliar a eficiência de controle de diferentes herbicidas e associações, em distintas doses, sobre plantas rebrotadas de *Euphorbia heterophylla* no período outonal, após o cultivo de feijão em segunda safra.
Métodos: O experimento foi conduzido a campo, em delineamento de blocos ao acaso com quatro repetições, com treze tratamentos: Testemunha; glyphosate (868 e 1736 g ha-1); metsulfurom (1,2 e 2,4 g ha-1); 2,4-D (335 e 670 g ha-1); metsulfurom + 2,4-D (1,2 + 335 g ha-1 e 2,4 + 670 g ha-1); iodosulfurom (1,75 e 3,5 g ha-1); triclopyr (48 e 96 g ha-1). Aos 35 dias após aplicação dos herbicidas foi avaliada a fitotoxidade, altura de plantas, número de sementes por planta e massa seca da parte aérea.
Resultados: O uso de glyphosate em ambas as doses testadas proporciona controle satisfatório da rebrota de plantas de E. heterophylla.
Conclusões: O uso de metsulfurom + 2,4-D (2,4 + 670 g ha-1) se destaca como alternativa eficiente quando não é possível o uso de herbicidas de ação total, demonstrando elevada fitotoxidade (94%) e redução de matéria seca de parte aérea (89%).

Palavras-chave: *E. heterophylla*, eficiência de controle, misturas de herbicidas, difícil controle.

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Short Communication

The control of mature weeds in agriculture demands high costs and more complex management strategies. They present higher tolerance to herbicides in post-emergence than young plants up to 10 cm (Norsworthy et al., 2014). In some plants, such as pastures, the abrupt cut provokes a compensatory growth effect, with fast regeneration and dry matter production higher than in uncut plants (Andreasen et al., 2002).

Regrowth weeds tend to present different morphologic, physiologic, and biochemical apparatus. They generally show a lower ratio between biomass (regrowth area) and the radicular system, reducing herbicide interception capacity and reducing the amount of product absorbed by plants. After removing the aerial part, the remaining radicular system works as a reserve for new sprouts, which develop vigorously. Besides that, the wholly developed radicular system permits a higher soil exploration, absorbing water and nutrients with higher efficiency, helping in the rapid growth rate and the development. They also have a higher metabolic capacity, activating defense genes against stresses and enzyme apparatus that permit quick activation and more efficient defense through biotic and abiotic stresses (Coetzer et al., 2001; Haarmann et al., 2020).

Even after regrowth, weeds can produce a large number of seeds, feeding the soil seed bank due to their vast reserves of carbohydrates (Mager et al., 2006). The younger they are cut and the higher the cutting height, the greater the regrowth capacity and production of seeds (Haarmann et al., 2020).

Unfavorable climatic conditions, such as radiation excess, elevated temperature, and water deficiency, can increase the deposition of epicuticular waxes and leaf thickness and cause variations in the composition of chlorophylls in more developed plants. This fact can influence the absorption and translocation of herbicides in the plant and the quality and coverage of the herbicide application

(Salomão et al., 2021; Trezzi et al., 2020).

Among the weed species of difficult control, the wild poinsettia (*Euphorbia heterophylla*) stands out of the flowed emergency, elevated adaptation to soy and beans crop systems, and high herbicide tolerance, especially for more developed plants present high regrowth capacity. Besides that, this species presents biotypes with simple resistance to acetolactate synthase (ALS) inhibitors and glyphosate and multiple to ALS and protoporphyrinogen oxidase (PPO) inhibitors (Heap, 2021).

Few studies have been done about the control of *Euphorbia heterophylla* regrowth plants in agriculture and the behavior characterization of the different herbicides (Haarmann et al., 2020; Andreasen et al., 2002). Concerning this scenario, studies are essential for controlling alternatives of regrowth species.

Thus, this study aims to evaluate the use of different herbicides, isolated and associated, in different doses, to control *Euphorbia heterophylla* regrowth plants in the fall period after the cultivation of beans in a second harvest.

The experiment was conducted in field conditions, in a crop located in the city of Vitorino, Paraná, Brazil (26° 16'48.2 "S 52°47'27.9 "W), with an altitude of 796 m. The local climate is classified as Cfb (humid mesothermal climate with mild summers) according to Köppen and Geiger classification (1928). The soil is classified as Latossolo Vermelho distrofico. Temperature and humidity conditions during the experiment period are described in Figure 1. The chemical and physical attributes of soil are presented in Table 1.

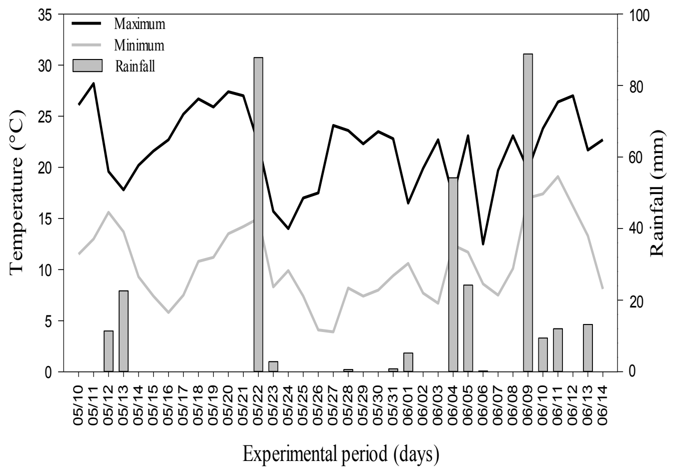


Figure 1. Rainfall, minimum and maximum temperature during the experimental period in 2020 in Vitorino region.

Table 1. Chemical and physical properties of the soil in the 0 to 20 cm layer.

pH	OM	Al^{3+}	H+Al	Ca^{2+}	Mg^{2+}	K	P	V	Sa	Si	Cl
$CaCO^3$	g dm^{-3}	cmol$_c$ dm^{-3}					mg dm^{-3}	%			
5.4	36.2	0.0	5.7	5.9	3.8	0.2	8.4	63.3	18.0	18.0	64.0

[1]OM: Organic matter; V: base saturation; Sa: Sand; Si: Silt; Cl: Clay.

During the fall from May 10th to June 14th, 2020, the trial was carried out after the mechanized harvest of a common bean crop that presented a plant's infestation of *Euphorbia heterophylla* in the flowering stage. The experiment was conducted in a randomized block design (RBD) with four replications, in experimental units with a useful area of 2 x 6 m (12 m^2). The area was maintained in fallow for approximately 40 days, in which the regrowth of *Euphorbia heterophylla* plants occurred. The herbicide applications were performed when plants reached 4 to 5 leaves, with an average height of 5 cm. The plant's density was adjusted manually for 8.5 plants m^{-2}. The 13 treatments tested in this study are described in Table 2.

The herbicide applications were performed with a CO_2 pressurized backpack sprayer, equipped with a fan-type nozzle XR110.02, utilizing a spray volume of 200 L ha^{-1}. At the moment of application, the weather condition was a clear sunny sky, with a temperature of 17°C, relative humidity of 85%, and wind speed of 5 km h^{-1}.

Thirty-five days after the herbicide applications (DAA), the percentage of control of *E. heterophylla* was visually determined, according to Frans et al. (1986) scale. In a sample of 10 plants per experimental unit, the plant height was determined by measuring the plant's base to the apical meristem. Other variables analyzed were the number of seeds per plant and the dry shoot biomass. The data relating to the number of seeds per plant and dry biomass were relativized, using as a reference the comparison group without herbicide application.

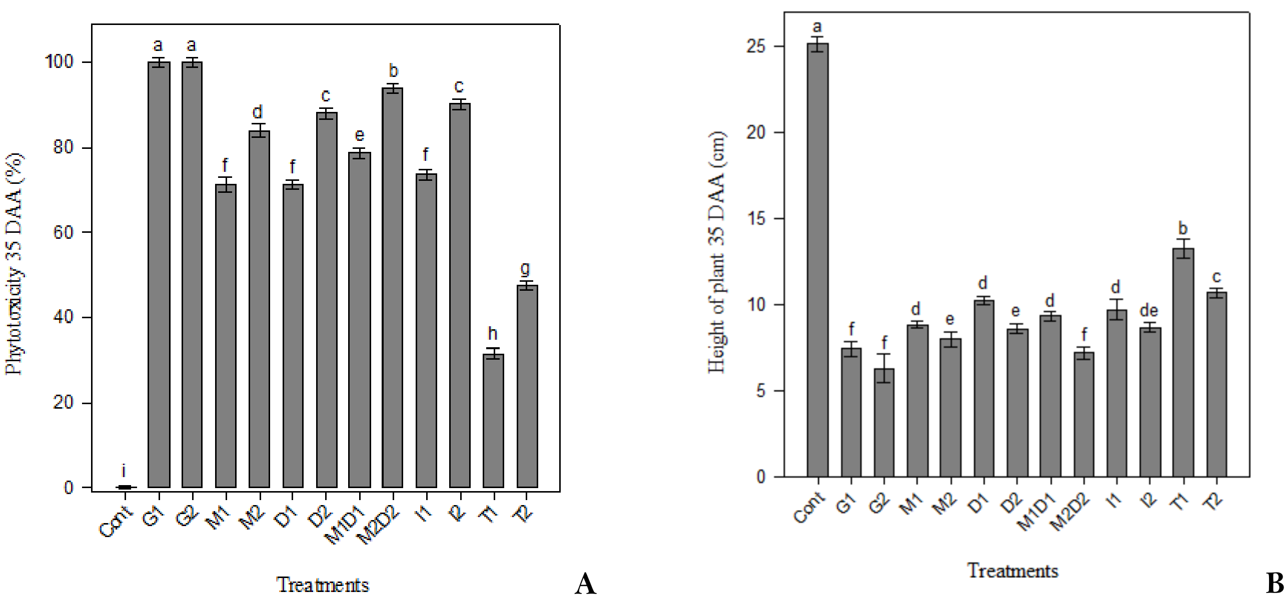
Table 2. Treatments, herbicides e rate used to control *Euphorbia heterophylla* regrowth plants in autumn period.

Treatments	Herbicide	Rate (g ai ha^{-1})
Control	None	-
G1	Glyphosate	868
G2	Glyphosate	1736
M1	Metsulfurom	1.2
M2	Metsulfurom	2.4
D1	2.4-D	335
D2	2.4-D	670
M1D1	Metsulfurom + 2.4-D	1.2 + 335
M2D2	Metsulfurom + 2.4-D	2.4 + 670
I1	Iodosulfurom	1.75
I2	Iodosulfurom	3.5
T1	Triclopyr	48
T2	Triclopyr	96

The data were submitted to the analysis of variance (ANOVA) and, when significant ($p \leq 0.05$), the measures were compared by Tukey's test ($p \leq 0.05$) using the software R Studio (Ferreira et al., 2018). The graphics were made with the software Sigma Plot 12.0.

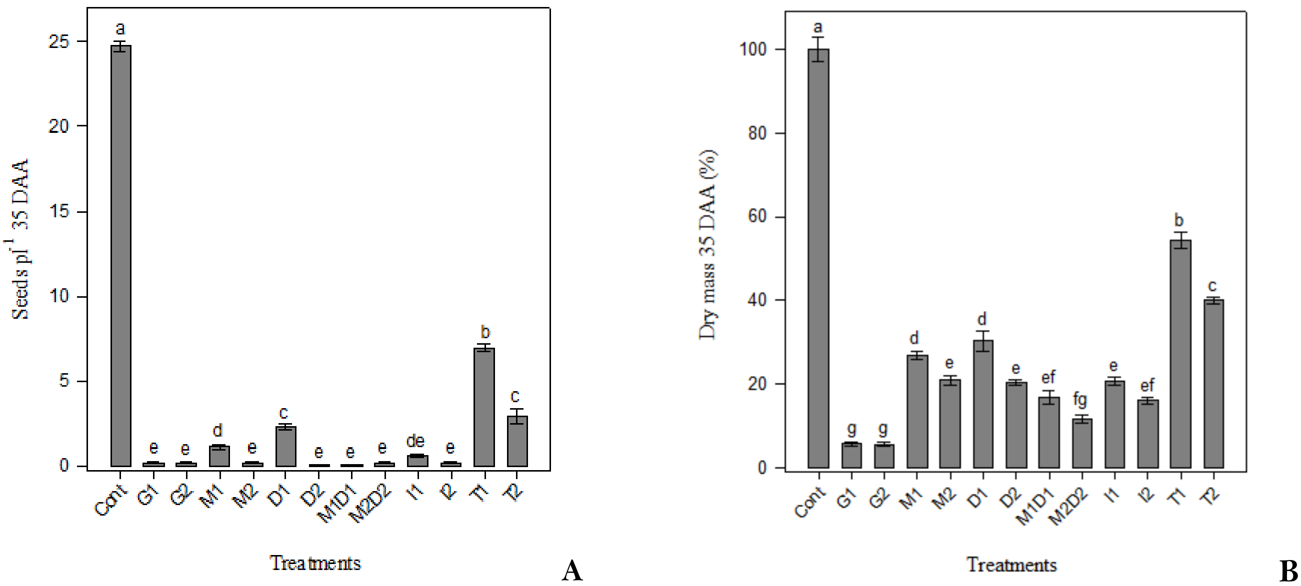
The treatments with glyphosate (G1 = 868 and G2 = 1736 g ha^{-1}) provided total control of *E. heterophylla*, overcoming the other treatments (Figure 2). The metsulfuron + 2,4-D (M2D2 = 2.4 + 670 g ha^{-1}) treatment was the second most efficient (94% of efficiency), followed by iodosulfuron (I2 = 3.5 g ha^{-1}) and 2.4-D (D2 = 670 g ha^{-1}) with 90 and 88% of control, respectively, proving to be viable alternatives for the control of *Euphorbia heterophylla* regrowth plants. However, an efficiency reduction of 6, 10, and 12% were perceived, respectively, compared with the glyphosate control (868 and 1736 g ha^{-1}).

Triclopyr (T1 = 48 and T2 = 96 g ha^{-1}) presented the less effective control (Figure 2). This effect can also be observed in determining plant height (Figure 3), demonstrating the low efficiency of this herbicide in controlling *E. heterophylla* regrowth plants. For this variable, the treatments with glyphosate (868 and 1736 g ha^{-1}) and metsulfuron + 2,4-D (2.4 + 670 g ha^{-1}) did not differ from each other, demonstrating to be the most promising, with height reductions of 70, 74, and 71%, respectively, when compared to the control without application (Figure 3).



DAA: Days after application; Cont: None; G1: Glyphosate 868 g ha^{-1}; G2: Glyphosate 1736 g ha^{-1}; M1: Metsulfurom 1,2 g ha^{-1}; M2: Metsulfurom 2,4 g ha^{-1}; D1: 2,4-D 335 g ha^{-1}; D2: 2,4-D 670 g ha^{-1}; M1D1: Metsulfurom + 2,4-D 1,2 e 335 g ha^{-1}; M2D2: Metsulfurom + 2,4-D 2,4 e 670 g ha^{-1}; I1: Iodosulfurom 1,75 g ha^{-1}; I2: Iodosulfurom 3,5 g ha^{-1}; T1: Triclopyr 48 g ha^{-1}; e T2: Triclopyr 96 g ha^{-1}. Bars denote the mean standard error. Columns followed by the same letter do not differ statically by Tukey's test ($p \leq 0.05$).

Figure 2. Phytotoxicity (%) (a) and height of plants (cm) (b) of *Euphorbia heterophylla* regrowth plants at 35 DAA (days after application) in the autumn period, using different herbicides.



DAA: Days after application; Cont: None; G1: Glyphosate 868 g ha^{-1}; G2: Glyphosate 1736 g ha^{-1}; M1: Metsulfurom 1,2 g ha^{-1}; M2: Metsulfurom 2,4 g ha^{-1}; D1: 2,4-D 335 g ha^{-1}; D2: 2,4-D 670 g ha^{-1}; M1D1: Metsulfurom + 2,4-D 1,2 e 335 g ha^{-1}; M2D2: Metsulfurom + 2,4-D 2,4 e 670 g ha^{-1}; I1: Iodosulfurom 1,75 g ha^{-1}; I2: Iodosulfurom 3,5 g ha^{-1}; T1: Triclopyr 48 g ha^{-1}; e T2: Triclopyr 96 g ha^{-1}. Bars denote the mean standard error. Columns followed by the same letter do not differ statically by Tukey's test ($p \leq 0.05$).

Figure 3. Seed production (a) and dry mass (%) (b) of *Euphorbia heterophylla* regrowth plants at 35 DAA (days after application) in the autumn period, using different herbicides.

The use of a full action herbicide, such as glyphosate, is often not a viable option in the fall. This herbicide would control the cover plants that emerged, such as black oat and ryegrass, both the plants implanted through mechanical seeding and the voluntary ones, which are present in the soil seed bank from previous crops with this propose. Besides that, a glyphosate-resistant *E. heterophylla* biotype was recently reported in the north of the state of Paraná, Brazil (Heap, 2021). Thus, considering the limitations described, the use of metsulfuron associated with 2.4-D (2.4 + 670 g ha^{-1}) would be the most indicated treatment because it does not damage the cover crops and efficiently controls the *E. heterophylla* regrowth plants.

A higher reduction in the production of *E. heterophylla* seeds was observed in the glyphosate treatments 868 and 1736 g ha^{-1}, metsulfuron 2.4 g ha^{-1}, 2.4-D 670 g ha^{-1}, metsulfuron + 2.4-D 1.2, and 335 g ha^{-1}; metsulfuron + 2.4-D 2.4 and 670 g ha^{-1}, and iodosulfuron 3.5 g ha^{-1} (Figure 3). These treatments provided a reduction close to 100% compared with the control. The treatment with the highest seed production was triclopyr 48 g ha^{-1}; (72%), followed by triclopyr 96 g ha^{-1} (88%), which did not differ from 2,4-D 335 g ha^{-1} (90%), and metsulfuron 1.2 g ha^{-1} (95%). Iodosulfuron (1.75 g ha^{-1}) with 97% seed production reduction did not differ from metsulfuron (1.2 g ha^{-1}), with a decline close to 100% in the number of seeds.

Although the herbicides differed in their capacity to reduce seed production, generally, all of them were very efficient since regrowth plants of *E. heterophylla* tend to produce a considerable number of seeds due to their carbohydrate stores (Mager et al., 2006). This fact indicates that herbicides applied in an isolated way or associated with others acted on metabolic pathways, causing different effects, such as reducing the production of essential amino acids and a significant increase in the production of toxic compounds in plants. This fact resulted in the targeting of reserves to maintain its primary metabolism and repair the damage caused, which harmed the plants' development and reproductive structures.

The dry shoot biomass result (Figure 3) was similar to the other variables, with glyphosate (868 and 1736 g ha^{-1}) presenting a higher percentage reduction (94%) compared to the control; however, it did not differ from metsulfuron + 2.4-D (2.4 + 670 g ha^{-1}) (89%). The triclopyr (48 g ha^{-1}) was the less effective (45%), followed by triclopyr 96 g ha^{-1} (60%), 2.4-D (335 g ha^{-1}) (70%), and metsulfuron (1.2 g ha^{-1}) (73%) that did not differ from each other.

It is highlighted the additive effect in the association of metsulfuron + 2.4-D, in both doses (1.2 g ha^{-1} and 335 g ha^{-1}; 2.4 g ha^{-1} and 670 g ha^{-1}), presenting complementarity between them in their action in the plant (Agostineto et al., 2016; Matthews, 1994). Gheno et al. (2020) observed an improvement in the control of *Conyza* spp. when metsulfuron and 2.4-D were associated compared with their isolated use. Andrade et al. (2018) determined an additive effect for the mixture of glyphosate + metsulfuron to control *Digitaria insularis*.

Therefore, the use of glyphosate in both doses tested (868 and 1736 g ha^{-1}) provides adequate control of *E. heterophylla* regrowth plants. As an alternative to full action herbicides, the use of metsulfuron + 2.4-D (2.4 + 670 g ha^{-1}) presents itself as an efficient option with high phytotoxicity (94%) and the capacity to reduce dry mass (89%).

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