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Herbicide Selectivity to the KS2019 Castor Bean Hybrid

Seletividade de herbicidas ao híbrido de mamona KS2019
Selectividad de Herbicidas para el Híbrido de Ricino KS2019

Victor Hugo Sousa Silva – Instituto Federal de Educação, Ciência e Tecnologia do Triângulo Mineiro (IFTM), Campus Uberlândia, MG.
Fernanda Batista Lima – Instituto Federal de Educação, Ciência e Tecnologia do Triângulo Mineiro (IFTM), Campus Uberlândia, MG.
Reinaldo Silva Oliveira Canuto – Instituto Federal de Educação, Ciência e Tecnologia do Triângulo Mineiro (IFTM), Campus Uberlândia, MG. reinaldo@iftm.edu.br

Abstract:
The castor bean productivity obtained in the 2021/2022 harvest reached 894 kg.ha-1, a value that was already considered double that of the previous harvest. Currently, in the 2025/2026 harvest, it is expected to harvest 2028 kg.ha-1 of grains. This record increase in oilseed production, in a short time, occurred due to technological advances and agronomic knowledge applied to the management of castor beans in different edaphoclimatic conditions. However, for productivity levels to be continuously surpassed, harvest after harvest, research to improve the phytotechnical management of the crop has been an essential factor. Given this scenario, one aspect related to agronomic management that has generated doubts is the choice of herbicides that can be applied to control weeds but do not cause phytotoxicity to the crop. Thus, the objective of this work was to evaluate the selectivity of herbicides to castor bean crops, specifically to the KS2019 hybrid. The experiment had a completely randomized design with 13 treatments and 3 replications and was carried out in the nursery of IFTM Campus Uberlândia. The treatments consisted of: control; clomazone + carfentrazone and s-metolachlor applied immediately after sowing (i.e., in the "plant-apply" modality); clomazone + carfentrazone and s-metolachlor (with a 50% higher dose compared to the previous treatment) after sowing; flumioxazin + s-metolachlor after sowing; diclosulan after sowing; sulfentrazone after sowing; clomazone + carfentrazone and s-metolachlor after sowing and s-metolachlor applied at the V10 phenological stage; clomazone + carfentrazone and s-metolachlor after sowing and s-metolachlor applied at the V10 phenological stage; clomazone + carfentrazone and s-metolachlor after sowing and s-metolachlor applied at the V20 phenological stage; clomazone + carfentrazone and s-metolachlor after sowing. The treatments consisted of: sowing and s-metolachlor + chlorimuron applied at the V20 phenological stage; clomazone + carfentrazone and s-metolachlor after sowing and bentazone applied at the V20 phenological stage; clomazone + carfentrazone and s-metolachlor after sowing and flumioxazin at the V10 stage; clomazone + carfentrazone and s-metolachlor after sowing and fomesafen at the V10 stage. The KS2019 hybrid was sown in 8L pots containing clay soil. Phytotoxicity was evaluated on castor bean plants 7, 14, and 21 days after the application of each treatment. The results showed the selectivity of the pre-emergent herbicides clomazone + carfentrazone and s-metolachlor to the castor bean crop. The herbicides fomesafen and flumioxazin were not selective when applied at the phenological stage. V10 of the castor bean plant that had previously received a spraying with clomazone + carfentrazone and s-metolachlor immediately after sowing, in the "plant-apply" method.

Keywords:
Chemical control; Weeds; Grain yield; Ricinus communis L.

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Resumo:
A produtividade de mamona obtida na safra de 2021/2022 atingiu 894 kg.ha-1, valor que já havia sido considerado como o dobro da safra anterior. Atualmente, na safra de 2025/2026, espera-se colher 2028 kg.ha-1 de grãos. Este aumento recorde na produção da oleaginosa, em pouco tempo, ocorreu em função dos avanços tecnológicos e do conhecimento agronômico aplicado à condução da mamoneira em diferentes condições edafoclimáticas. Entretanto, para que os patamares de produtividades sejam continuamente superados, safra após safra, a realização de pesquisas para o aprimoramento da condução fitotécnica da cultura tem sido um fator essencial. Diante deste cenário, um dos aspectos relacionados ao manejo agronômico que tem gerado dúvidas é a escolha de herbicidas que possam ser aplicados para o controle de plantas daninhas, mas que não causem fitotoxicidade à cultura. Assim, o objetivo deste trabalho foi avaliar a seletividade de herbicidas à cultura da mamona, especificamente ao híbrido KS2019. O experimento apresentou delineamento inteiramente casualizado com 13 tratamentos e 3 repetições e foi realizado no viveiro do IFTM Campus Uberlândia. Os tratamentos foram constituídos por: testemunha; clomazone+carfentrazone e s-metolacloro aplicados logo após a semeadura (ou seja, na modalidade "plante-aplique"; clomazone+carfentrazone e s-metolacloro (com dose 50% maior em relação ao tratamento anterior) após a semeadura; flumioxazina + s-metolacloro após a semeadura; diclosulan após a semeadura; sulfentrazone após a semeadura; clomazone + carfentrazone e s-metolacloro após a semeadura e s-metolacloro aplicado no estádio fenológico V10; clomazone + carfentrazone e s-metolacloro após a semeadura e s-metolacloro aplicado no estádio fenológico V10; clomazone + carfentrazone e s-metolacloro após a semeadura e s-metolacloro aplicado no estádio fenológico V20; clomazone + carfentrazone e s-metolacloro após a semeadura e s-metolacloro + clorimuron aplicado no estádio fenológico V20; clomazone + carfentrazone e s-metolacloro após a semeadura e bentazona aplicado no estádio fenológico V20; clomazone + carfentrazone e s-metolacloro após a semeadura e flumioxazina no estádio V10; clomazone + carfentrazone e s-metolacloro após a semeadura e fomesafen no estádio V10. O híbrido KS2019 foi semeado em vasos de 8L contendo solo argiloso. Aos 7, 14 e 21 dias após a aplicação de cada tratamento foi realizada a avaliação da fitotoxicidade nas plantas de mamona. Os resultados evidenciaram a seletividade dos herbicidas pré-emergentes clomazone + carfentrazone e s-metolacloro à cultura da mamona. Os herbicidas fomesafen e flumioxazina não foram seletivos quando aplicados no estádio fenológico V10 da mamoneira que recebeu, previamente, a pulverização com clomazone + carfentrazone e s-metolacloro logo após a semeadura, na modalidade "plante-aplique".

Palavras-chave:
Controle químico; Plantas daninhas; Produtividade de grãos; Ricinus communis L.

Resumen:
La productividad de ricino obtenida en la cosecha 2021/2022 alcanzó 894 kg.ha-1, valor que ya había sido considerado el doble de la cosecha anterior. Actualmente, en la cosecha 2025/2026, se espera obtener 2028 kg.ha-1 de granos. Este aumento récord en la producción de la oleaginosa, en poco tiempo, ocurrió debido a los avances tecnológicos y al conocimiento agronómico aplicado al manejo del ricino en diferentes condiciones edafoclimáticas. Sin embargo, para que los niveles de productividad continúen superándose cosecha tras cosecha, la realización de investigaciones para perfeccionar el manejo fitotécnico del cultivo ha sido un factor esencial. Ante este escenario, uno de los aspectos relacionados con el manejo agronómico que ha generado dudas es la elección de herbicidas que puedan aplicarse para el control de

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malezas sin causar fitotoxicidad al cultivo. Así, el objetivo de este trabajo fue evaluar la selectividad de herbicidas para el cultivo de ricino, específicamente para el híbrido KS2019. El experimento presentó un diseño completamente aleatorizado con 13 tratamientos y 3 repeticiones y fue realizado en el vivero del IFTM Campus Uberlândia. Los resultados evidenciaron la selectividad de los herbicidas preemergentes clomazone + carfentrazone y s-metolacloro para el cultivo de ricino. Los herbicidas fomesafen y flumioxazina no fueron selectivos cuando se aplicaron en el estadio fenológico V10 de la planta de ricino que había recibido previamente una pulverización con clomazone + carfentrazone y s-metolacloro inmediatamente después de la siembra, en la modalidad "siembre-aplique".

Palabras clave:
Control químico; Malezas; Productividad de granos; Ricinus communis L.

Introduction

In the context of the historical analysis of castor bean cultivation in Brazil, there have been significant advances in the productive aspects presented in the crop surveys carried out by CONAB (National Supply Company). In the 2021/2022 crop season, a cultivated area of 50,100 hectares was recorded, with a production of 35,800 tons of grains and a productivity of 894 $kg.ha^{-1}$ (Conab, 2022). Currently, the expectation is to harvest 159,800 tons of grains from an area of 78,800 hectares, which would result in a productivity of 2028 $kg.ha^{-1}$ · Compared to the 2024/2025 crop season, the values for production, cultivated area, and grain productivity will increase by 59.7%, 13.2%, and 41.3%, respectively (Conab, 2026). The increased production levels of castor beans in Brazil are the result of a combination of several factors, ranging from genetic improvement of the *Ricinus species. from* the generation of new hybrids to the analysis of the crop's agronomic performance in different edaphoclimatic regions, coupled with the insertion of techniques and technologies applied to its management.

Castor bean cultivation has been adopted mainly in the second crop season (or "safrinha") due to its potential to generate good productivity levels even in environments with low water availability (Catão Júnior *et al.* , 2024) and for assisting in the management of nematodes that could affect summer crops such as soybeans (Martins, 2021). However, from the moment one chooses to cultivate castor beans, agronomic factors must be carefully observed so that the expected productivity levels for a given hybrid are achieved. Among the recommended cultural practices, there is a constant need for weed control before and after sowing of the oilseed. However, further research is still needed to define the best control strategies for weed management.

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Although some research related to weed competition control in castor bean cultivation has been carried out, until mid-2022, there were only 2 herbicides registered for the crop with the Ministry of Agriculture, Livestock and Supply (Brazil, 2022).

Research on chemical weed control in castor bean crops is still in its early stages, which raises questions about the effective management of weed competition under field conditions, as well as the possibility of phytotoxic effects of some herbicides on the crop. Therefore, determining the selectivity of herbicides to castor beans is fundamental for obtaining high-quality fruits and grains with the highest possible productivity. Thus, with expectations of an expanding market, castor bean production urgently needs research that demonstrates the effect of the largest possible number of active ingredients in eliminating or reducing interference caused by weeds. Offering effective options for controlling monocot and dicot weeds is necessary to address the potential emergence of weeds resistant to the few herbicides registered for the crop with the Ministry of Agriculture, Livestock and Supply.

Therefore, given the above, the objective of this work was to evaluate the selectivity of pre- and post-emergent herbicides for weed management in castor bean crops.

2. Materials and methods

The experiment was conducted in the seedling production nursery of IFTM Campus Uberlândia, located at coordinates 18º45'48" South latitude and 48º17'21" West longitude. The altitude of the site is 648 meters and the climate classification is Aw according to Köppen - Geiger (Peel; Finlayson ; McMahon, 2007).

The research was conducted in a completely randomized design with 3 replications and a 13x3 factorial arrangement, with the first factor consisting of herbicide treatments and the second factor consisting of the phytotoxicity evaluation times , i.e., 7, 14, and 21 days after the application of each treatment. The herbicide treatments consisted of:

1. Witness;

2. Clomazone (600 g ai /ha) + carfentrazone (15 g ai /ha) and s- metolachlor (1920 g ai /ha) applied immediately after sowing;

3. Clomazone (900 g ai /ha) + carfentrazone (22.5 g ai /ha) and s- metolachlor (2400 g ai /ha) applied immediately after sowing;

4. Flumioxazin (100 g a.i./ha) + s- metolachlor (1920 g a.i./ha) applied immediately after sowing;

5. Diclosulam (25.2 g a.i./ha) applied immediately after sowing;

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6. Sulfentrazone (600 g a.i./ha) applied immediately after sowing;

7. Clomazone (600 g ai./ha) + carfentrazone (15 g ai./ha) and s- metolachlor (1920 g ai./ha) applied immediately after sowing and s- metolachlor (960 g ai./ha) applied at the V10 phenological stage of the castor bean crop.

8. Clomazone (600 g ai./ha) + carfentrazone (15 g ai./ha) and s- metolachlor (1920 g ai./ha) applied immediately after sowing and s- metolachlor (1920 g ai./ha) applied at the V10 phenological stage of the castor bean crop.

9. Clomazone (600 g ai./ha) + carfentrazone (15 g ai./ha) and s- metolachlor (1920 g ai./ha) applied immediately after sowing and s- metolachlor (1920 g ai./ha) applied at the V20 phenological stage of the castor bean crop.

10. Clomazone (600 g ai./ha) + carfentrazone (15 g ai./ha) and s- metolachlor (1920 g ai./ha) applied immediately after sowing and s- metolachlor (1440 g ai./ha) + chlorimuron (10 g ai./ha) applied at the V20 phenological stage of the castor bean crop.

11. Clomazone (600 g ai./ha) + carfentrazone (15 g ai./ha) and s- metolachlor (1920 g ai./ha) applied immediately after sowing and bentazone (360 g ai./ha) applied at the V20 phenological stage of the castor bean crop.

12. Clomazone (600 g ai./ha) + carfentrazone (15 g ai./ha) and s- metolachlor (1920 g ai./ha) applied shortly after sowing and flumioxazine (20 g ai./ha)

13. Clomazone (600 g ai./ha) + carfentrazone (15 g ai./ha) and s- metolachlor (1920 g ai./ha) applied immediately after sowing and falesafen (125 g ai./ha).

Each experimental plot consisted of three pots containing 8 L of clay soil, classified as dystrophic Red Latosol. In each pot, 4 seeds of the KS2019 hybrid were initially placed at a depth of 3 cm. One hour after sowing, herbicides were applied using a " plant-apply " system. Subsequently, after emergence, the seedlings were thinned, leaving only one per pot.

pre- and post-emergent herbicides was carried out with the support of a CO2 cylinder $_{\text{regulated}}$ to a pressure of 30 lb.in $^{-2}$ with a bar equipped with 4 fan-type nozzles 110 03 and with an application speed regulated to apply 300 L.ha - ^{1} of spray volume of each herbicide.

The evaluation of the phytotoxic effect of herbicides after treatment application was carried out at 7, 14, and 21 days following the scale proposed by the EWRC (1964) and presented by Carmargo (1972). The scale ranges from 0 to 9, with scores assigned as follows:

1 = absence of phytotoxicity symptoms.

2 = minor changes (discoloration and deformation) visible in some plants.

3 = small visible changes in many plants (chlorosis and curling).

4 = severe discoloration or reasonable deformation, without necrosis occurring.

5 = necrosis of some leaves, accompanied by deformation in leaves and shoots.

6 = reduction in plant size, leaf curling and necrosis.

7 = more than 80% of the leaves destroyed.

8 = extremely severe damage, leaving only small green areas on the plants.

9 = death of the plants.

Knott test , both with a significance level of 5%. The statistical program SISVAR (Ferreira, 2011) was used.

3. RESULTS AND DISCUSSION

After spraying with pre- and post-emergent herbicides on castor bean crops, phytotoxicity scores were assigned according to the manifestation of symptoms 7, 14, and 21 days after application. As shown in Table 1, there was a significant interaction ($F=12.72$; $p<0.05$) between the factors "herbicides" and "evaluation time". Thus, it is possible to affirm that there was a relationship of dependence between the application of herbicides and the phytotoxicity effects observed on different days after spraying.

Table 1. Analysis of Variance of phytotoxicity scores for castor bean crops as a function of herbicides and evaluation time after application of each treatment. Means analyzed with a significance level of 5% using the ANOVA *F- test.*

FV	GL	SQ	QM	Fc	Pr> Fc
Herbicides (H)	12	540.34	45.03	1053.67	0.000
Assessment time (AT)	2	0.73	0.37	8.60	0.004
H*TA	24	13.04	0.54	12.72	0.000
Error	78	3.33	0.043		
Total corrected	116	557.45			
CV (%) = 10.70%					

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The application of the herbicides clomazone (600 g a.i./ha) + carfentrazone (15 g a.i./ha) and s- metolachlor (1920 g a.i./ha) immediately after sowing castor beans, and s-metolachlor (1920 g a.i./ha) applied at the V10 phenological stage of the crop, caused phytotoxicity, although it was mild. When this same treatment was applied at the V20 phenological stage, there was no manifestation of phytotoxicity in the castor bean plants. This fact highlights the importance of knowing the most appropriate phenological stage for the application of each herbicide in the crop. Although the active ingredients and doses were the same, the phytotoxic effect was greater when s- metolachlor was applied at the earlier phenological stage, i.e., at V10. Although a phytotoxic effect was observed at 7 days after application (DAA) at this stage, it was noted that the castor bean plants recovered their development over time, and by 21 DAA there were practically no symptoms of phytotoxicity (Table 2).

Table 2. Phytotoxicity scores for castor bean plants at 7, 14, and 21 days after application of each herbicide treatment.

Treatment	7 DAA	14 DAA	21 DAA
1. Witness	1.0 Aa	1.0 Aa	1.0 Aa
2. Clomazone (600 g ai /ha) + carfentrazone (15 g ai /ha) and s- metolachlor (1920 g ai /ha) applied immediately after sowing	1.0 Aa	1.0 Aa	1.0 Aa
3. Clomazone (900 g ai /ha) + carfentrazone (22.5 g ai /ha) and s- metolachlor (2400 g ai /ha) applied immediately after sowing	1.0 Aa	1.0 Aa	1.0 Aa
4. Flumioxazin (100 g a.i./ha) + s- metolachlor (1920 g a.i./ha) applied immediately after sowing.	1.0 Aa	1.0 Aa	1.0 Aa
5. Diclosulam (25.2 g a.i./ha) applied immediately after sowing.	1.0 Aa	1.0 Aa	1.0 Aa
6. Sulfentrazone (600 g a.i./ha) applied immediately after sowing.	1.0 Aa	1.0 Aa	1.0 Aa
7. Clomazone (600 g ai./ha) + carfentrazone (15 g ai./ha) and s- metolachlor (1920 g ai./ha) applied immediately after sowing and s- metolachlor (960 g ai./ha) applied at the V10 phenological stage of the castor bean crop.	1.0 Aa	1.0 Aa	1.0 Aa

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8. Clomazone (600 g ai./ha) + carfentrazone (15 g ai./ha) and s- metolachlor (1920 g ai./ha) applied immediately after sowing and s- metolachlor (1920 g ai./ha) applied at the V10 phenological stage of the castor bean crop.	2.7 Bc	2.0 Bb	1.0 Aa
9. Clomazone (600 g ai./ha) + carfentrazone (15 g ai./ha) and s- metolachlor (1920 g ai./ha) applied immediately after sowing and s- metolachlor (1920 g ai./ha) applied at the V20 phenological stage of the castor bean crop.	1.0 Aa	1.0 Aa	1.0 Aa
10. Clomazone (600 g ai./ha) + carfentrazone (15 g ai./ha) and s- metolachlor (1920 g ai./ha) applied immediately after sowing and s- metolachlor (1440 g ai./ha) + chlorimuron (10 g ai./ha) applied at the V20 phenological stage of the castor bean crop.	1.0 Aa	1.0 Aa	1.0 Aa
11. Clomazone (600 g ai./ha) + carfentrazone (15 g ai./ha) and s- metolachlor (1920 g ai./ha) applied immediately after sowing and bentazone (360 g ai./ha) applied at the V20 phenological stage of the castor bean crop.	1.0 Aa	1.0 Aa	1.0 Aa
12. Clomazone (600 g ai./ha) + carfentrazone (15 g ai./ha) and s- metolachlor (1920 g ai./ha) applied immediately after sowing and flumioxazin (20 g ai./ha) applied at the V10 phenological stage of the castor bean crop.	5.7 Cc	4.7 Cb	3.7 Ba
13. Clomazone (600 g ai./ha) + carfentrazone (15 g ai./ha) and s- metolachlor (1920 g ai./ha) applied immediately after sowing and fomesafen (125 g ai./ha) applied at the V10 phenological stage of the castor bean crop.	7.7 dB	9.0 dB	9.0 Ca
CV = 10.70%			

Scott-Knott test at a 5% significance level.

Other herbicide combinations that did not demonstrate selectivity to castor bean crops were the application of flumioxazin (20 g ai./ha) at the V10 phenological stage of the castor bean crop after it had been previously sprayed with clomazone (600 g ai./ha) + carfentrazone (15 g ai./ha) and s- metolachlor (1920 g ai./ha) immediately after sowing in the " plant-apply " system.

fomesafen (125 g ai./ha) applied at the V10 phenological stage of the castor bean crop did not show selectivity , which was sprayed with clomazone (600 g ai./ha) + carfentrazone (15 g ai./ha) and s- metolachlor (1920 g ai./ha) applied immediately after sowing.

In the two cases mentioned above, it became evident that the herbicides flumioxazin and fomesafen were not selective to castor bean plants, since the phytotoxicity scores were high. In the case of flumioxazin , leaf curling was observed on all leaves at 7 DAA (days after application). Although this curling decreased over time , a high phytotoxicity score was still observed at 21 DAA, which makes the recommendation of this herbicide unfeasible for castor bean plants sprayed with clomazone + carfentrazone and s- metolachlor in the " plant-apply " system . Regarding the application of fomesafen , the plants showed severe leaf curling and necrosis as early as 7 DAA, resulting in the death of the weeds. At 14 and 21 DAA, the castor bean plants were dead.

In conclusion, this study found that the herbicides flumioxazin and fomesafen, applied at the V10 phenological stage of castor bean plants after prior treatment with clomazone + carfentrazone and s- metolachlor immediately after sowing in a " plant-apply " system, were not selective to the crop.

Regarding the application of s- metolachlor at the V10 phenological stage of castor bean after the combined application of clomazone + carfentrazone and s- metolachlor in the " plant-apply " system, the authors of this study suggest conducting further field experiments to determine if the observed phytotoxicity could result in reduced castor bean grain yield. The phytotoxicity score observed at 7 DAA was low, but only further field tests can yield results that prove that the low phytotoxicity observed will not negatively impact castor bean productivity.

4. Conclusion

The pre -emergent herbicides clomazone (600 g ai./ha) + carfentrazone (15 g ai./ha) and s- metolachlor (1920 g ai./ha) applied immediately after sowing the castor bean (in the “ plant-apply ” method) and s- metolachlor (1920 g ai./ha) applied at the V10 phenological stage were selective to castor bean.

Post-emergent herbicides fomesafen (125 g ai./ha) and flumioxazine (20 g ai./ha) , applied at V10, were not selective to the castor bean crop.

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