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Article

Selectivity of Pre and Postemergence Herbicides in Single or Combined Applications in Castor Crop

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Abstract: One of the main challenges in castor crop (*Ricinus communis* L.) production is efficient weed management mainly due to limited options of selective herbicides. This study evaluated the selectivity of herbicides applied alone or in combination in pre- and postemergence applications in castor crop. Two field experiments were carried out under irrigation conditions in a semi-arid region of Northeast Brazil. It was found that the visual symptoms of phytointoxication of the herbicides used on castor were mild in both experiments. Consequently, there were no significant interferences on plant height, number of racemes, and grain (seed) yield. Pre-emergence applications (g ha^{-1}) of trifluralin (1800), pendimethalin (1500), clomazone (750), clomazone + trifluralin (750 + 1800), and clomazone + pendimethalin (750 + 1500) followed by chlorimuron-ethyl in postemergence (15 g ha^{-1}) are selective to castor. The application (g ha^{-1}) of pendimethalin + clomazone (1000 + 500) in pre-emergence, associated with chlorimuron-ethyl (10 and 15), metamitron (2800 and 4200), ethoxysulfuron (60 and 80), or halosulfuron-methyl (75 and 112.5) in one or two applications in postemergence, as single or split applications, in an interval of 14 days, are selective to castor crop.

Keywords: *Ricinus communis*; weed control; tolerance; herbicide dose; sequential application; tank mixture

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1. Introduction

Castor oil is widely used in the industry for containing ricinoleic acid and unique properties in its fatty acids, being a valuable input for the production of lubricants, paints, plastics, drugs, and cosmetics [1,2]. However, the growth in world consumption has been limited by low agricultural production capacity, with great potential for expanding the cultivated area and increasing productivity [3,4].

The averages of castor production, cultivation area and grain yield in the last five years in Brazil were 24,400 tons, 36,700 ha, and 634.9 kg ha^{-1}, respectively. The majority of production (93%) is concentrated in the Brazilian Northeast region [5], which is limited by the water regime and low technology adoption. Brazil's productivity is considered extremely low, demanding the improvement of their production systems to allow further expansion of cultivated area with that crop. In this scenario, coupled with the development of more productive and precocious recent genetic materials and the development of mechanized harvesting, castor bean cultivation has shown potential to regions of higher technological level, such as the Brazilian cerrado, as an alternative rotation and succession (second harvest) to soybean, cotton, and corn cultivation [6].

Weed management has stood out among the main challenges in castor crop. The C_3 photosynthetic metabolism and the slow initial growth of the crop, as well as the low sowing densities and wide spacing between rows used in the traditional production areas are among the main causes of low competitiveness of castor plant [7–10]. Even though weed community composition depends on their region, environmental conditions, and agricultural practices, Asteraceae, Convulvulaceae, Malvaceae, Rubiaceae, and Poaceae are common plant families found in castor production areas [11–16].

As in other crops, integrated management provides greater sustainability of agricultural production systems [13,17]. Nonetheless, chemical weed control is considered the most efficient method, mainly for mechanized production systems, due to the greater economic return [8]. However, for the establishment of castor weed management programs, the greatest difficulty relates to the options of selective herbicides, as full-action herbicides in directed-jet only between the rows do not efficiently control the infestation located in the row and present a higher risk of phytotoxicity [12,18].

As a management strategy, there has been a greater number of studies in the literature for selective herbicides with predominant efficacy for the control of grass weed species in the pre-emergence of castor, especially trifluralin, pendimethalin, clomazone, and s-metolachlor [15,19–24]. For postemergence applications, the main alternatives are graminicides with the acetil-CoA carboxylase (ACCase) enzyme inhibiting action mechanism: fluazifop-p-butyl, sethoxydim, haloxyfop-methyl, quizalofop-p-ethyl, propaquizafop, butroxydim, clethodim, and fenoxaprop-p-ethyl [25,26]. For the control of broadleaf weed species, the herbicide chlorimuron-ethyl is considered the only selective latifolicide for use in postemergence of castor crop [15,16,27]. Recently, the herbicides halosulfuron-methyl and ethoxysulfuron have emerged as possibilities for postemergence control of sedges and volunteer soybean (*Glycine max*) in areas where castor can be used in crop succession systems [16,28].

Due to the need for greater knowledge about the selectivity of herbicides in order to improve the management of weeds in castor crop [26,29], new studies that identify safer combination strategies used in pre- or postemergence can be configured as new alternatives to expand options and provide a greater spectrum of control of weed species [8,15,16]. These combinations can involve the herbicide tank mixture in a single application or even associations in split applications throughout the crop cycle, used before or after the emergence of castor and weeds.

Regarding herbicide weed resistance being one of the main challenges for modern agriculture, the combination of herbicides with different action mechanisms is an important tool to avoid or manage this problem [30]. The possibilities of combination between herbicides with inhibition of the microtubules (trifluralin and pendimethalin), synthesis of carotene (clomazone), acetolactate synthase (ALS) enzyme (chlorimuron-ethyl, ethoxysulfuron, halosulfuron-methyl), and photosystem II (metamitron) can represent an important strategy for castor cultivation. This strategy can be even more important for 5-enolpyruvylshikimate-3-phosphate synthase (EPSPs)-resistant weeds in traditional soybean production regions where glyphosate use is intensive [31].

In this context, the objective of this study was to define the selectivity of herbicides applied alone or in combination in pre- and postemergence applications in castor crop.

2. Materials and Methods

This study was conducted in two experiments, the first one related to the selectivity of pre-emergence herbicides applied alone or in tank mixtures, at different doses, combined or not with a postemergence application of chlorimuron-ethyl. The second experiment involved selectivity of pendimethalin mixed with clomazone in pre-emergence, associated with postemergence herbicide doses in a single or two combined applications in sequence. The information from the first assay was also used to identify selective pre-emergence herbicides to be associated with the postemergence ones in the second experiment.

The first experiment was conducted in Apodi, Rio Grande do Norte, Brazil (5°37′ S, 37°49′ W; 120 m a.s.l.) in 2015. The local climate is BSh′ (Köppen) tropical warm semi-arid with rains predominantly between December and April. The mean temperature during the experimental period, from July to November, was 29.0 °C, and there was no rain. The genotype BRS Energia (short stature, indehiscent fruits) was planted under irrigated conditions at 37,500 plants ha^{-1} (0.8 m $\times$ 0.33 m). Fertilization was performed according to Severino et al. (2006): 30 kg ha^{-1} N, 60 kg ha^{-1} P_2O_5, and 60 kg ha^{-1} K_2O at planting, and a dressing composed of 60 kg ha^{-1} N at 20 days after emergence [32]. The soil is classified as sandy-clay-loam eutrophic Cambisol, with 56.8% sand, 33.7% clay, and 9.5% silt, whose chemical characteristics were pH in water = 6.3, Ca^{+2} = 50 mmol$_c$ dm^{-3}, Mg^{+2} = 24 mmol$_c$ dm^{-3}, Na^{+} = 8.3 mmol$_c$ dm^{-3}, H^{+}+Al = 23 mmol$_c$ dm^{-3}, Al^{+3} was absent, P = 23 mg dm^{-3}, K^{+} = 6.9 mmol$_c$ dm^{-3}, and organic matter = 6.5 g kg^{-1}.

The plants were sprinkle irrigated, and the total water applied was 550 mm, from planting to harvest at 120 days after emergence (DAE). Fourteen treatments were conducted, using a 7 $\times$ 2 + 1 factorial combination. The factors consisted of seven pre-emergence herbicides, combined or not with a postemergence herbicide, and a weekly hand-hoeing control treatment. Pre-emergence herbicide treatments (g ha^{-1}) were trifluralin (1800), pendimethalin (1500), clomazone (750), clomazone + trifluralin (500 + 1200), clomazone + pendimethalin (500 + 1000), clomazone + trifluralin (750 + 1800), and clomazone + pendimethalin (750 + 1500). Chlorimuron-ethyl (15 g ha^{-1}) was used as a postemergence herbicide.

A completely randomized experimental design with four replications was used. Each plot had six rows (7 m in length), and data were collected from the central rows. Pre-emergence herbicides were applied on the same day as sowing. The postemergence herbicide was sprayed on the whole plot at 20 days after pre-emergence application (DAPA) when castor plants had between four and six true leaves (BBCH 14 and 16, respectively). Herbicides were applied using a compressed CO_2 backpack sprayer delivering 200 L ha^{-1}, equipped with a bar with flat fan spray nozzles (BD 11002), at 200 kPa cm^{-2} pressure and at 40 cm height in relation to the crop. During the experimental period, the plots of all treatments were kept free of infestation by hoe weeding to avoid competition with weeds that could not be controlled by the herbicides. Herbicide phytotoxicity on castor plants was visually evaluated at 20 DAPA, using the scale proposed by the European Weed Research Council (1964), and before postemergence application [33]. Data on plant height, number of racemes per plant, and grain yield were obtained at castor harvesting time (120 DAE).

The second experiment was conducted in Barbalha, Ceará State, Brazil (07°17′ S and 39°16′ W; 415 m a.s.l.) in 2016. The local climate is BSh′ (Köppen), warm semi-arid with rains predominantly between December and April. The mean temperature during the experimental period, from June to October, was 28.9 °C, and there was no rain. Castor seeds cv. EVF-701 (short stature, indehiscent fruits) were sown under irrigated conditions at 50.000 plants ha^{-1} (0.8 m $\times$ 0.25 m). Fertilization was performed according to Severino et al. (2006): 80 kg ha^{-1} P_2O_5 in the row, at sowing, and 57 kg ha^{-1} N applied at 30 and 50 DAE (flowering phase) [32]. The soil is classified as Entisol sandy-loam, with 58.3% sand, 15.6% clay, and 26.1% silt, whose chemical characteristics were pH in water = 6.5, Ca^{+2} = 59.6 mmol$_c$ dm^{-3}, Mg^{+2} = 27.6 mmol$_c$ dm^{-3}, Na^{+} = 2.3 mmol$_c$ dm^{-3}, H^{+}+Al = 10.7 mmol$_c$ dm^{-3}, CEC = 102.5 mmol$_c$ dm^{-3}, V = 89.5%, Al^{+3} was absent, P = 27.9 mg dm^{-3}, K^{+} = 2.3 mmol$_c$ dm^{-3}, S = 91.8 mmol$_c$ dm^{-3}, and organic matter = 12.5 g kg^{-1}.

Preventive weed management was made based on selectivity results obtained in the first assay, using pendimethalin (1000 g ha^{-1}) + clomazone (500 g ha^{-1}) in pre-emergence in the total area, except for the control treatment, which plots received infestation control by hoe weeding. The plants were sprinkle irrigated, and the total water applied was 642 mm from planting to harvest at 117 DAE.

The fifteen treatments consisted of a control and the following postemergence herbicides (g ha^{-1}): chlorimuron-ethyl (10), chlorimuron-ethyl (15), metamitron (2800), metamitron (4200), ethoxysulfuron (60), ethoxysulfuron (80), halosulfuron-methyl (75), halosulfuron-methyl (112.5), chlorimuron-ethyl /metamitron (10/2800), chlorimuron-ethyl/ethoxysulfuron (10/60), chlorimuron-ethyl/halosulfuron-methyl (10/75), metamitron/ethoxysulfuron (2800/60), metamitron/halosulfuron-methyl (2800/75), and ethoxysulfuron/halosulfuron-methyl (60/75).

A completely randomized experimental design with four replications was used. Each plot measured 3.2 × 5 m (16 m^2), and data were collected from the central rows, excluding 0.5 m in the borders. The treatments including two postemergence herbicides consisted of sequential applications. The first herbicide was applied when the plants had six true leaves. When the treatment included a second herbicide, the spraying was performed two weeks after the first one. Spreader-sticker adjuvant was added (0.3% v/v) to the spray solutions of metamitron, and mineral oil was added at 0.05% and 0.5% (v/v) to chlorimuron-ethyl and halosulfuron-methyl solutions, respectively. The herbicides were applied using a CO_2 pressurized backpack sprayer, equipped with a bar with expanded use flat fan nozzles (XR 11002VS), spaced 0.5 m, at 160 kPa pressure and spray solution consumption of 200 L ha^{-1}. As in the first experiment, during the experimental period, all treatments were kept free of infestation by hoe weeding. The evaluation methods were the same as in the first experiment. Phytointoxication [26] and plant height were evaluated at 35 days after the second postemergence application (DASPA). The number of racemes and seed yield were recorded at harvesting (117 DAE).

The data from both experiments were subjected to analysis of variance and Tukey test (5%) for comparison of means. The Assistat 6.2 and Sisvar 5.6 softwares were used for the statistical analysis in first and second experiment, respectively [34,35]

3. Results

3.1. Pre-Emergence Herbicides Combined with Chlorimuron-Ethyl in Postemergence

Very mild symptoms of phytointoxication were observed on castor plants twenty days after the pre-emergence application, characterized by only chlorosis of some leaves on castor plants, except for treatment with trifluralin (1800 g ha^{-1}) where there were no symptoms of visual injuries (Table 1). Clomazone applied at a dose of 750 g ha^{-1} or in a tank mixture with trifluralin (1800 g ha^{-1}) and pendimethalin (1500 g ha^{-1}) resulted in phytointoxication symptoms significantly higher than the other treatments.

Table 1. Phytointoxication, plant height, racemes per plant, and seed yield of castor (*Ricinus communis* L.) under weed management combining pre- and postemergence herbicides.

Pre-Emergence Herbicides	Dose (g ha^{-1})	Phytointoxication [1]	Plant Height (m) [2]	Racemes per Plant [2]	Grain Yield (kg ha^{-1}) [2]
Control	0	1.0 c	1.77 ns	7.4 ns	2810 ns
Trifluralin	1800	1.0 c	1.78	6.3	2632
Pendimethalin	1500	1.5 b	1.81	6.4	2501
Clomazone	750	2.0 a	1.76	5.8	2572
Clomazone + trifluralin	500 + 1200	1.4 b	1.77	6.7	2431
Clomazone + pendimethalin	500 + 1000	1.7 b	1.80	6.1	2762
Clomazone + trifluralin	750 + 1800	2.4 a	1.76	6.7	2476
Clomazone + pendimethalin	750 + 1500	2.5 a	1.74	7.4	2762
Postemergence herbicide					
Without chlorimuron-ethyl	-	-	1.79 ns	6.0 b	2504 ns
With chlorimuron-ethyl	15	-	1.76	6.9 a	2685
CV (%)	-	31.9	9.4	17.6	18.5

Means followed by the same letter are not significantly different according to the Tukey test (5%). ns—Not significantly different according to F test of the analysis of variance (5%). [1] on 20 days after pre-emergence application; [2] at harvesting time.

However, the plants recovered without negative effects for the variable's height, number of racemes per plant, and grain yield (Table 1). In addition, the complementary application in postemergence of the herbicide chorimuron-ethyl, even when combined with pre-emergence herbicides, did not cause symptoms of plant phytointoxication and significant interference on plant height.

For the variable number of racemes per plant, a significant increase was observed when using the combination of herbicides in pre-emergence with chorimuron-ethyl in postemergence (Table 1). However, the increase in this variable did not cause gains in grain yield, which was similar to the non-application of chorimuron-ethyl.

3.2. Pre-Emergence Application of Pendimethalin + Clomazone Combined to Postemergence Herbicides

All herbicide treatments applied in postemergence, combined with the use of pendimethalin + clomazone (1000 + 500 g ha^{-1}) in pre-emergence caused only mild phytointoxication to the castor crop at 35 DASPA (Table 2). Thus, due to the low level of visual injuries, represented only by mild chlorosis of the leaves (Figure 1), no differences between the treatments were characterized, regardless of the dose applied or if the herbicides were applied in single or split application. For the variables plant height, number of racemes, and grain yield, there were also no significant differences between the treatments studied

Table 2. Phytointoxication, plant height, racemes per plant, and seed yield of castor (*Ricinus communis* L.) under weed management combining pre and postemergence herbicides.

Treatments [1]	Dose (g ha^{-1})	Phytointoxication [2]	Plant Height (m) [2]	Racemes per Plant [3]	Grain Yield (kg ha^{-1}) [3]
Control	0	1.0 b	0.83 ns	3.8 ns	1675.4 ns
Chlorimuron-ethyl	10	2.0 a	0.79	4.3	2167.1
Chlorimuron-ethyl	15	2.0 a	0.77	4.3	1469.3
Metamitron	2800	2.0 a	0.89	4.2	2211.6
Metamitron	4200	2.0 a	0.83	4.0	1828.6
Ethoxysulfuron	60	2.0 a	0.84	3.8	1818.9
Ethoxysulfuron	80	2.0 a	0.83	3.9	1909.9
Halosulfuron-methyl	75	2.0 a	0.84	4.8	1638.4
Halosunfuron-methyl	112.5	2.0 a	0.77	4.2	1618.5
Chlorimuron-ethyl/metamitron	10/2800	2.0 a	0.83	4.0	1499.4
Chlorimuron-ethyl/ethoxysulfuron	10/60	2.0 a	0.81	3.9	1830.4
Chlorimuron-ethyl/halosulfuron-methyl	10/75	2.0 a	0.84	4.3	1730.0
Metamitron/ethoxysulfuron	2800/60	1.8 a	0.94	3.9	1948.1
Metamitron/halosulfuron-methyl	2800/75	2.0 a	0.87	4.4	1619.6
Ethoxysulfuron /halosulfuron-methyl	60/75	2.0 a	0.84	3.9	1733.1
CV %		6.7	9.2	14.6	22.1

Means followed by the same letter are not significantly different according to the Tukey test (5%). ns—Not significantly different according to F test of the analysis of variance (5%). [1] all treatments, excepted control, received a pre-emergence application (g ha^{-1}) of pendimethalin (1000) + clomazone (500); [2] on 35 days after the second postemergence application; [3] at harvesting time.

Figure 1. Details of visual injuries of castor leaves caused due to chlorimuron-ethyl (**a**), ethoxysulfuron (**b**), halosulfuron-methyl (**c**), and metamitron (**d**) on 35 days after the second postemergence application in the second experiment.

4. Discussion

Despite the slight visual phytointoxication observed with the herbicide applications in pre-emergence at 20 DAPA, it was found that trifluralin (1800 g ha^{-1}), pendimethalin (1500 g ha^{-1}), and clomazone (750 g ha^{-1}) did not cause harmful effects to the development of castor crop (Table 1). However, it is important to note that the safe dose of these herbicides to the crop can vary depending on the chemical and, mainly, physical characteristics of the soil. In general, for sandier soils, the dose should be the lowest recommended by the herbicide manufacturer, which has been confirmed for castor crop with compounds that act as inhibitors of microtubule formation, such as pendimethalin and trifluralin [21,22]. In this research, the selectivity for the same doses studied in sandy texture soils with trifluralin and pendimethalin corroborates the information obtained by Sofiatti et al. (2012) and Maciel et al. (2012), respectively [15,20]. Grichar et al. (2015) also found tolerance of castor to clomazone in clay-sandy soil in higher doses (840 and 1680 g ha^{-1}) [23].

Although the highest doses resulted in the highest levels of visual phytointoxication, all treatments with herbicide mixtures did not affect the plant development and grain yield. Sofiatti et al. (2012) verified that the mixture clomazone + trifluralin was also selective for castor in the same soil type of the first experiment [15].

Considering the results from both experiments (Tables 1 and 2), it was verified that all the treatments with clomazone + pendimethalin (500 + 1000 g ha^{-1}) resulted in mild phytointoxication and did not cause harmful effects to the development of castor crop. This fact can be most related to the similar sand content of these soils, despite higher differences for clay and organic matter concentration. These physical and chemical characteristics influence the sorption, degradation, and, consequently, the herbicide availability and its effects on crops [36].

In relation to other possibilities of tank mixtures using clomazone, Costa et al. (2015) also observed no injury with clomazone + s-metolachlor in sandy soil (650 + 576 g ha^{-1}) for the BRS Energia castor cultivar [16]. These results therefore indicate that any of the herbicides are safe to be used in castor crop. However, in order to minimize the phytointoxication to crop it is recommended that when these compounds are used in mixture, the doses are reduced.

Tank mixtures of herbicides can considerably expand the effect on weed species. Consequently, weed control efficiency can be improved. In this context, the mixtures clomazone + trifluralin and clomazone + pendimethalin, in general, are more suitable to use in castor crop. These herbicides are mainly effective on grass and some broadleaf weed species. Therefore, while pendimethalin and trifluralin control important weeds like *Althernantera tenella* Colla and some species of the *Amaranthus* genus, clomazone contributes to the control of *Sida rhombifolia* L., *Bidens pilosa* L., *Spermacoce latifolia* Aubl, *Commelina benghalensis* L., and some *Ipomoea* spp. [37–39].

In this paper, in addition to the selective effect of all herbicide treatments in pre-emergence, the same was verified when a complementary application of chlorimuron-ethyl (15 g ha^{-1}) was carried out in the postemergence of the crop. Thus, it is emphasized that weed management programs that involve the application of pre- and postemergence herbicides tend to be more effective, as they contribute to increasing the control spectrum especially for broadleaf species, as found in other studies with castor crop [15,16,24].

Regarding the results obtained in the second experiment, where a pre-emergence application of pendimethalin + clomazone was performed, complemented with postemergence herbicide applied as single or split application, the symptoms of mild phytointoxication did not result in significant interference for the variables plant height, number of racemes, and grain yield of castor EVF-701 cultivar (Table 2).

In general, the results allow to infer that even after the use of pendimethalin + clomazone (1000 + 500 g ha^{-1}), in conditions of new weed flush, it is still possible to choose herbicide applications. In this context, chlorimuron-ethyl, ethoxysulfuron, and halosulfuron-methyl could be used to manage species that are difficult to control, but with no history of resistance to acetolactate synthase (ALS) inhibitors. For conditions with confirmed presence of species resistant to ALS inhibitors, the best option would be the metamitron, as it is a photosystem II inhibiting herbicide, as well as the sequential applications that include this herbicide (chlorimuron-ethyl/metamitron; metamitron/ethoxysulfuron and metamitron/halosulfuron-methyl), which support the management of resistant species. Likewise, for less problematic species and with no history of resistance to ALS, it would still be possible to use sequential applications involving chlorimuron-ethyl/ethoxysulfuron, chlorimuron-ethyl/halosulfuron-methyl, and ethoxysulfuron/halosulfuron-methyl in the respective studied doses.

It is important to highlight that all the evaluated herbicide doses applied alone or in sequences in an interval of 14 days, initiated with castor in a stage of six true leaves, were selective to the crop. Maciel et al. (2017), when using chlorimuron-ethyl (15 and 20 g ha^{-1}) in stages between four and seven true leaves of the castor cultivars Lyra, Iris, Savana, and AL Guarany 2002, found higher levels of phytointoxication and reduced yield with the highest dose, depending on the formulation of the herbicide and the cultivar used [27].

In the present study, the selectivity of metamitron, ethoxysulfuron, and halosulfuron-methyl was confirmed in the field as they did not interfere with height at 35 DASPA and primarily affected grain yield. Almeida et al. (2018), when applying the same herbicides and doses at the stage of four to six true leaves, also did not observe reduction in the initial development of castor [28]. According to the authors, halosulfuron-methyl and ethoxysulfuron were the best options for the control of volunteer soybean in castor crop. Assis et al. (2014) observed that the dose of 36 g ha^{-1} of ethoxysulfuron was enough for the control of volunteer soybean in the 3-trifoliate stage [40]. The control of this infesting species is essential in areas where castor is grown in succession to soybean crop, as occurs in the Brazilian Cerrado region.

As mentioned, the advantage of associating active ingredients with different mechanisms of action, whether in mixture or in sequential applications, contributes to reducing the risk of resistant weed biotypes [17]. This benefit gains importance mainly in producing regions where castor can be grown in succession or rotation of crops with intensive use of herbicides, such as corn, cotton, and, mainly, soybean, in which resistance cases are common, mainly to the herbicide glyphosate, an inhibitor of the EPSP enzyme [41]. Thus, in relation to herbicides typically latifolicides, the main option found has remained in relation to chlorimuron-ethyl [8,15,16,27]. Although metamitron is used to control eudicots species, it is recommended for pre and initial postemergence applications [39]. Therefore, further studies should still consider the evaluation of the selectivity of metamitron for castor in earlier stages, so that in practice its use also coincides with the initial stages of weeds, and thus guarantee its greater control effectiveness.

5. Conclusions

Pre-emergence applications of the doses of the herbicides (g ha^{-1}) trifluralin (1800), pendimethalin (1500), clomazone (750) isolated or in tank mixtures, clomazone + trifluralin (750 + 1800), and clomazone + pendimethalin (750 + 1500) (always associated with postemergence chlorimuron-ethyl (15 g ha^{-1})) were selective to castor crop.

The application (g ha^{-1}) of pendimethalin + clomazone (1000 + 500) in pre-emergence associated with chlorimuron-ethyl (10 and 15), metamitron (2800 and 4200), ethoxysulfuron (60 and 80) or halosulfuron-methyl (75 and 112.5) in postemergence, applied in isolation, are selective to castor. These same herbicides, in the lowest doses, are also selective when two applications are made in sequence with an interval of 14 days.

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