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Evaluation of intoxication caused by post-emerging herbicides in cassava crop in two times of application

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Abstract: This study aimed to evaluate the selectivity of post-emergent herbicides in cassava in two application times. The experiments were carried out in a greenhouse at the Federal University of Tocantins - UFT, Campus Gurupi. The experimental designed was completely randomized arranged in a 5x2 factorial scheme, composed by the combination of 5 herbicide molecules with different mechanisms of action (mesotrione, carfentrazone-ethyl, chlorimuron-ethyl, nicosulfuron and imazethapyr) applied in two seasons, 30 and 45 days after emergence (DAE), with four repetitions. The cultivar used was "*Cacau melhorada*". The visual intoxication of the culture was evaluated. The treatments based on mesotrione, and chlorimuron-ethyl were not toxic to the culture, promoting results similar to those observed for control. There were differences in the level of tolerance to the studied herbicides, between the times of application of the herbicides.
Keywords: chemical control, *Manihot esculenta*, weed control.

Avaliação de intoxicação causada por herbicidas pós-emergentes na cultura da mandioca em duas épocas de aplicação

Resumo: O objetivo do trabalho foi avaliar a seletividade herbicidas pós-emergentes em mandioca em duas épocas de aplicação. Os experimentos foram conduzidos em casa de vegetação na Universidade Federal do Tocantins – UFT, Campus Gurupi. O delineamento inteiramente casualizados - DIC, disposto em esquema fatorial 5x2, compostos pela combinação de 5 moléculas de herbicidas de diferentes mecanismos de ação (mesotrione, carfentrazone-ethyl, chlorimuron-ethyl, nicossulfuron e imazethapyr) e uma testemunha com ausência de aplicação, aplicados em duas épocas, 30 e 45 dias após a emergência (DAE), com quatro repetições. A cultivar utilizada foi a *Cacau melhorada*. Foram avaliadas a intoxicação visual da cultura. Os tratamentos à base de mesotrione, e chlorimuron-ethyl não foram tóxicos à cultura promovendo resultados semelhantes aos observados para testemunha. Constatou diferenças no nível de tolerância aos herbicidas estudados, entre as épocas de aplicação dos herbicidas.

Palavras-chaves: controle químico, *Manihot esculenta*, controle de daninhas.

Introduction

Cassava (*Manihot esculenta* Crantz) is an important crop for world food security due to its wide adaptability to low natural fertility and irregular rain conditions, conditions that are limiting for most conventional crops (Adjebeng-Danquah and Safo-Kantanka, 2013). Although it is a rustic species with high diversity, the productivity of the crop is far below its productive potential. The inadequate management of weeds is among the main causes that contribute to the low yield of the crop (Albuquerque et al., 2008). The presence of weeds compromises growth, development, as well as photosynthetic characteristics (Aspiazu et al., 2010), resulting in a reduction in size, weight and number of roots.

Edible cassava intended for fresh consumption can have a cycle of less than one year and when grown for industrial purposes it can have a cycle of more than two years. As a result of the long period, the cultivation is subject to many cycles of infestation and weed competition, with greater favor for the plant architecture, cultivation density and slow initial growth of cassava (Silva et al., 2012a). The level of competition of weeds and cassava depends on the duration of the coexistence period and the phenological stage of the crop.

The two main methods used for weed control are mechanical control, through weeding, and chemical control through the application of herbicides. However, there is a lack of knowledge about the selectivity and effectiveness of chemical weed control alternatives in cassava culture. One of the bottlenecks in the efficient control of weeds in the cassava cultivation, at low cost, is the restricted number of registered herbicides and with few mechanisms of action available, especially for application in post-emergence (Biffe et al. 2010; Silva et 2012b). According to studies, it was observed that it is necessary to keep the crop free of weeds for at least 75 days after planting (DAP), to allow normal root development. Weed control should start with the first weeding at 25 DAP and the last at 75 DAP (Albuquerque, 2008; Albuquerque et al., 2012).

Although chemical control has advantages over other methods of weed control, it should be noted that this can only be practiced with the use of selective herbicides for the crop. In studies on herbicide selectivity, it is important to evaluate intoxications caused on plants (Galon et al., 2009). In this context, this research aimed to evaluate the selectivity of herbicides applied in post-emergence in cassava cultivation in two application times.

Material and methods

The study was carried out at the Federal University of Tocantins - UFT, Campus Gurupi, located in the southern region of the State of Tocantins (geographical coordinates: 11º 43 'S and 49º 04' W) and an altitude of 280 m. With a climate classified as humid tropical with little water deficiency (B1wA'a '), the average annual temperature is 29.5 ° C, with an average annual rainfall of 1,804 mm, with rainy summer and dry winter; Cerrado (Aw) by Köppen - Geiger (Peel; Finlayson and Mcmahon, 2007).

The experiment was carried out in a greenhouse in a protected environment. Soil classified as dystrophic Red-Yellow Latosol with medium texture was used (Embrapa, 2013), (30% clay, 50 silt and 65% sand). The chemical analysis of the soil showed a pH (CaCl) of 5.3; organic matter content of 1.8 g.kg^{-1}; P 10.5 mg dm^{-3} and K, Ca, Mg, Al, H + Al and effective cation exchangeability of 0.14; 2.1; 0.7; 0.0; 2.20; and 5.14 cmol.dm^{-3}, respectively. Corrections and necessary fertilizations were realized according to soil analysis and recommendations for the crop. Irrigations were performed daily, using an automatic micro-sprinkler system, based field capacity.

The experiment was implemented in a completely randomized design - DIC, arranged in a 5x2 factorial scheme, which consist of 10 treatments, a combination of 5 herbicide molecules with different mechanisms of action (mesotrione, carfentrazone-ethyl, chlorimuron-ethyl, nicosulfuron and imazethapyr) and a control with no application, applied at two times, 30 and 45 days after emergence (DAE), with four repetitions. Each pot with a volumetric capacity of 10 dm^{-3}, containing soil, represented an experimental unit.

Table 1. Classification and doses applied to cassava plants.

Commercial name	Common name (a.i)	Dose a.i. (g ha^{-1})	Mechanism of action
Callisto	mesotrione	144	Carotenoid Inhibitor
Aurora 400 EC	carfentrazone-ethyl	30	PPO inhibitor
Clorim	chlorimuron-ethyl	20	
Sanson 40 SC	nicosulfuron	60	ALS inhibitor
Vezir 100	imazethapyr	106	

a.i. – active ingredient

The stem cuttings of the cultivar "*Cacau Melhorada*" were purchased from a cassava producer in the region. Then, planting in pots was carried out in January 2018, with sprouting visible 8 days later. The herbicides were applied at 30 and 45 days after emergence when the plants were about 20 cm tall and about 15 leaves fully expanded. CO_2 pressurized backpack sprayer with constant pressure was used, equipped with a boom containing a fan tip, working at a height of 50 cm from the target, with a speed of 1 m $^{s-1}$ and a spray volume of 200 L ha $^{-1}$.

At 7, 14, 21 and 28 days after herbicide application (DAA), visual assessments of crop intoxication were made, using a percentage scale of grades ranging from 0 (zero) to 10 (ten), where 0 implies the absence of any injuries and 10 the death of plant, as shown in Table 2.

The results were subjected to analysis of variance by the F test and the averages were analyzed statistically by the LSD test, at 5% probability, due to selectivity experiments, aiming to demonstrate the absence of difference, where small differences are important to be detected (OAK et al., 2009). For this reason, in this work, a "t" test was used to compare the treatment means. The statistical software used was SISVAR (Ferreira, 2011).

Table 2. Visual symptoms of phytotoxicity (Azzi and Fernandez, 1968).

Concept	Grades	Note
Very slight	0 – 0.5	Small changes (discoloration, deformation) visible on some leaves. Zero score when no damage is observed.
Slight	0.6 – 10	Small changes (discoloration, deformation) visible on many leaves.
Moderate	1.1 – 2.0	Strong discoloration (yellowing) or reasonable deformation, without, however, necrosis (tissue death).
Acceptable	2.1 – 3.5	Necrotization (burning) of some leaves, especially in the margins, accompanied by deformation in leaves and buds.
Worrisome	3.6 – 4.5	More than 50% of the leaves and buds showing necrosis / deformation.
High	4.6 – 6.0	More than 80% of the plant showing necrosis / deformation and destroyed shoots.
Very tall	6.1 – 10	Extremely serious damage, leaving only small green areas in the plants. Note 10 for death of the plant.

Results and discussion

The summary of the analysis of variance for the toxicity characteristic of the herbicides is presented in Table 3, where the F values for the causes of variation and their interaction, and the unfolding degrees of freedom are presented. The time x herbicide interaction showed a significant effect at 7, 14, 21 and 28 days after application. There was a significant influence of herbicide factor at 7, 14, 21 and 28 days after application. There was an influence of the time of application, at 7 and 14 days after application.

Table 3. Summary of the analysis of variance and variation coefficient for plant toxicity as a function of the application of post-emergent herbicides and application times in Gurupi - TO, 2018.

VS	DF	Medium Square			
		7 DAA	14 DAA	21 DAA	28 DAA
Herbicide (H)	4	15.821**	9.821**	24.865**	50.240**
Time (T)	1	21.025**	1.806**	0.006ns	0.625 ns
H x T	4	1.821**	0.821**	0.553 **	1.734**
Residue	30	0.229	0.168	0.210	0.195
Average		1.72	1.71	1.73	2.05
CV %		27.75	23.99	26.40	21.59

ns = not significant; * = significant by F test at 5%, ** significant by F test at 1% probability.

The interaction herbicide and time of application was significant for all treatments at 7 DAA. Herbicides when applied at 30 DAE showed higher averages of toxicity with a significant difference in assessments at 7 and 14 DAA when compared to 45 DAE (Table 4). In the visual intoxication assessments shown in Table 4, it was found that at 7 days after application (DAA) the plants submitted to an application at 30 DAE of the herbicides mesotrione, chlorimuron-ethyl, imazethapyr and nicosulfuron showed slight changes, with yellowing spots, no differing statistically from each other. For the same time of application, the treatment with carfentrazone-ethyl showed higher values of intoxication among herbicides, with an average of 5.25%, where the plants presented deformations and necrosis points. In the second time at 45 DAE, the herbicide mesotrione showed no signs of intoxication and carfentrazone-ethyl showed a higher level of intoxication, but less damage when compared to the first time of application. In the time at 30 DAE, the plants found their structures less developed, with greater amounts of meristematic tissues, where the center of the physiological activity and cell division of the plant is found, which may have contributed to the higher level of stress provided by products chemicals and becoming more visually evident.

The herbicides nicosulfuron and imazethapyr caused high intoxication to cassava plants with evolution from 14 DAA. Agostinetto et al. (2002) found that the herbicide imazethapyr showed high values of visual intoxication, with increased damage up to 8 DAA and remaining high until 14 days.

Treatments with mesotrione and chlorimuron-ethyl, provided lower rates of visual intoxication and reduced level of intoxication over time, with no visible changes at 28 DAA in both application periods (Table 4). The results were similar to those observed by Silveira et al. (2012), where evaluating different doses of mesotrione in different cultivars, they observed that at the dose of 144 a.i. g ha^{-1}, the plants submitted presented symptoms of injuries that consisted of light whitening of the new leaves of the plants, with a level of intoxication of up to 22,5%. Agostinetto et al. (2002), obtained an increase in the toxicity level for the herbicide chlorimuron-ethyl up to 8 DAA and a reduction from 14 DAA. Ferreira et al. (2015) observed that the herbicides chlorimuron-ethyl and nicosulfuron applied 45 days after planting caused low intoxication in cassava plants until 23 DAA.

Despite the higher percentage of injuries observed in the treatment with the herbicide carfentrazone-ethyl in the first evaluation, there was a reduction in symptoms over time, with small changes visible in some leaves in the last evaluation. The plants recovered after the appearance of new leaves. The herbicide carfentrazone-ethyl is a contact product of non-systemic action of the chemical group triazolone, with mechanisms of action of competitive inhibition of the enzyme protoporphrinogen oxidase (PROTOX). Probably, due to this fact, the plants submitted to this treatment presented higher levels of intoxication in the first evaluation. With low mobility in the plant, this herbicide accumulates in the sprayed places and causes necrosis in the nearby tissues (Oliveira Junior, 2011).

Table 4. Toxicity of cassava plants due to the application of post-emergent herbicides and application times in Gurupi - TO, 2018.

Herbicide	a.i. (g ha^{-1})	Time of application	
		30 DAE	45 DAE
		Toxicity 7 Days After Application (%)	
Mesotrione	144	1.25 b A	0.00 c B
Carfentrazone E.	30	5.75 a A	2.62 a B
Chlorimuron	20	1.75 b A	0.62 bc B
Nicossulfuron	60	1.87 b A	0.87 b B
Imazethapyr	106	1.62 b A	0.87 b B
		Toxicity 14 Days After Application (%)	
Mesotrione	144	0.25 c A	0.37 c A
Carfentrazone E.	30	2.75 a A	1.75 b B
Chlorimuron	20	1.25 b A	0.25 c B
Nicossulfuron	60	2.75 a A	2.12 b B
Imazethapyr	106	2.62 a A	3.00 a A
		Toxicity 21 Days After Application (%)	
Mesotrione	144	0.00	0.12
Carfentrazone E.	30	1.37	1.12
Chlorimuron	20	0.25	0.12
Nicossulfuron	60	3.62	3.12
Imazethapyr	106	3.37	4.25
		Toxicity 28 Days After Application (%)	
Mesotrione	144	0.00	0.00
Carfentrazone E.	30	1.00	0.25
Chlorimuron	20	0.12	0.00
Nicossulfuron	60	4.50	4.87
Imazethapyr	106	4.00	5.75

Time of application	7 DAA	14 DAA	21 DAA	28 DAA
30 DAE	2.45 a	1.92 a	1.72 a	1.92 a
45 DAE	1.00 b	1.50 b	1.75 a	2.17 a

Averages followed by the same lowercase letter in the column and uppercase in the row, do not differ statistically, from each other, by the LSD test ($p > 0.05$). a.i. = active ingredient.

As noted, the results indicate that both mesotrione and chlorimuron-ethyl herbicides can be sprayed at 30 DAE and 45 DAE. Although it does not cause significant toxicity 21 days after application, the herbicide carfentrazone-ethyl caused high rates of intoxication at 7 DAA requiring further studies at the field level to assess the influence of this herbicide on the root productivity of the crop. The figure 1 shows visual symptoms of phytotoxicity of herbicides at two application timesm of spraying.

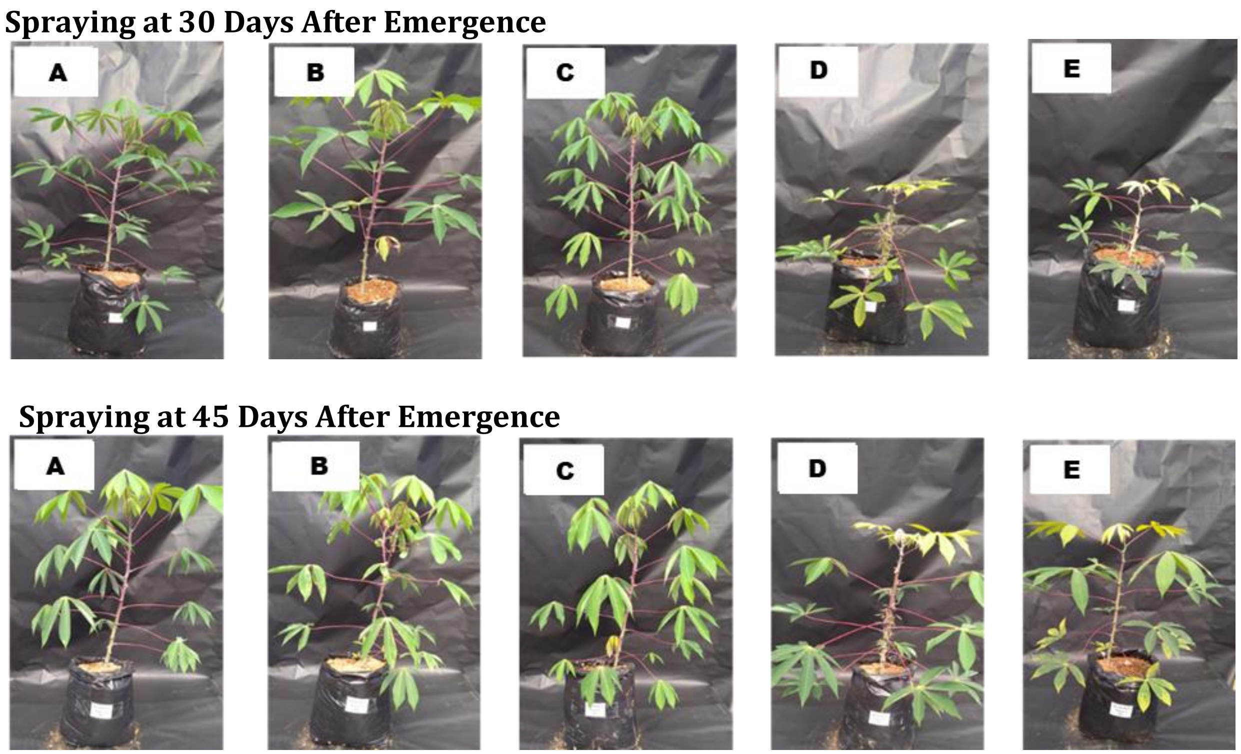

Figure 1. Visual symptoms of phytotoxicity of herbicides at two application times (A: mesotrione; B: carfentrazone-ethyl; C: chlorimuron-ethyl; D: nicosulfuron; E: imazethapyr). Photos captured at 75 days after emergence.

At the second time of application (45 DAE) were found fewer average values of phytotoxicity. The age of the plant affects the herbicide absorption, its translocation and activity in plants (Oliveira Júnior and Inoue, 2011). Young plants are more susceptible to herbicides than older ones, mainly because young plants have more meristematic tissues.

Conclusions

The herbicides mesotrione and chlorimuron-ethyl are highly selective to cassava regardless of whether applied to 30 or 45 DAE.

Cassava suffer fewer visual symptoms of phytotoxicity when the herbicides are applied at 45 DAE.

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