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Selectivity and herbicides efficiency pre-emergence applied in papaya crop[1]

Seletividade e eficácia de herbicidas aplicados em pré-emergência na cultura do mamoeiro

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Abstract - In papaya culture, there is little information on selective herbicides when pre-emergence applied. A field experiment was conducted to evaluate the selectivity and efficacy of herbicides pre-emergence applied to control weeds in papaya cultivation. The experiment was conducted in a randomized blocks design with four replications. The treatments were: ametryn (1500 g ha^{-1} i.a.), diuron (1500 g ha^{-1} i.a), ametryn + diuron (1500 + 1500 g ha^{-1} i.a.), flumioxazin (50 g ha^{-1} i.a.) and isoxaflutole (150 g ha^{-1} i.a.), applied pre-emergence of weeds and before transplanting the papaya seedlings, as well as two controls, one kept in clean through hoeing and another without weed control. At 7, 14, 21 and 28 days after application (DAA) of the herbicides visual assessments of intoxication in papaya plants were made at 0, 28, 42, 56 and 72 DAA, plant height and stem diameter were evaluated, and at 21, 42 and 63 DAA the dry matter weight of the weed plants were evaluated. The herbicides ametryne, diuron, flumioxazin and the mixture ametryn + diuron caused the death of papaya seedlings, and isoxaflutole caused poisoning in seedlings with subsequent recovery. The weed interference resulted in papaya plants with smaller stem diameter, although the plant height was not influenced.
Keywords: *Carica papaya*; chemical control; weeds

Resumo - Na cultura do mamoeiro, são escassas as informações sobre herbicidas seletivos quando aplicados em pré-emergência. Um experimento de campo foi realizado para avaliar a seletividade e eficácia de herbicidas aplicados em pré-emergência para o controle de plantas daninhas na cultura do mamoeiro. O experimento foi conduzido no delineamento experimental em blocos casualizados, com quatro repetições. Os tratamentos avaliados foram: ametryn (1500 g ha^{-1} i.a.), diuron (1500 g ha^{-1} i.a), ametryn + diuron (1500 + 1500 g ha^{-1} i.a.), flumioxazin (50 g ha^{-1} i.a.) e isoxaflutole (150 g ha^{-1} i.a.), aplicados em pré-emergência das plantas daninhas e antes do transplante das mudas de mamoeiro, além de duas testemunhas, sendo uma mantida no limpo por meio de capinas e outra sem controle de plantas daninhas. Aos 7, 14, 21 e 28 dias após

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aplicação (DAA) dos herbicidas foram realizadas avaliações visuais de intoxicação nas plantas de mamão, aos 0, 28, 42, 56 e 72 DAA, avaliou-se altura de plantas e diâmetro do caule, e aos 21, 42 e 63 DAA avaliou-se a massa da matéria seca das plantas daninhas. Os herbicidas ametryn, diuron, flumioxazin e a mistura ametryn + diuron causaram a morte das mudas de mamoeiro e isoxaflutole causou intoxicação nas mudas com posterior recuperação. A interferência das plantas daninhas resultou em plantas de mamão com menor diâmetro do caule, embora a altura de plantas não tenha sido influenciada.
Palavras-chaves: *Carica papaya*; controle químico; plantas daninhas

Introduction

Brazil is the largest producer of papaya, with 35.5 thousand hectares, producing 1.85 million tons in 2011. The major producing states are Bahia, Espirito Santo, Ceara and Rio Grande do Norte, which account for 50.05, 30.23, 6.07 and 3.74% of national production, respectively, totaling more than 90% of the Brazilian production (IBGE, 2013).

In the state of Rio Grande do Norte this culture has taken great social and economic importance for generating employment and income for municipal producers (Barreto et al., 2010). In 2011, the area harvested in the state was 1,992 hectares, with average yield of 34.4 t ha^{-1}, producing 69,410 tons of papaya and revenue of R$ 37.55 million (IBGE, 2013).

Among the various biotic factors that affect papaya culture, the interference of weeds that compete with culture for water, light and nutrients need to be highlighted; they may also host pests and diseases, and hinder cultivation operations and harvest. The crop most sensitive stage to weed interference occurs during its formation, especially in the first three months after transplantation (Ronchi et al., 2008).

The control method commonly adopted by the producers is the mechanical through grids or trimmers mainly between the planting rows (Dantas et al., 2013). During this period, up to four meadows are carried out, which costs may reach R$ 1,200.00 by hectare (Ronchi et al., 2008). Barreto et al. (2010) found that the cost of hoeing in a hectare is R$1,500.00 each year, representing approximately 7% of the culture total costs. These high control costs show the need for developing new technologies for weed management in papaya culture recently transplanted (Ronchi et al., 2008). In addition, the manual control of weeds in the rows, using hoes, has injured the papaya root system and stem, in addition to harming the irrigation system (drilling of drip hoses).

Therefore, the chemical control through the use of herbicides becomes a more effective alternative for containing several advantages such as: less dependence on labor; efficiency even during rainy season; efficient control of weeds in the rows and it does not affect the root system of crops; allows minimum tillage or direct seeding; and efficiency in controlling weed of vegetative propagation (Silva and Silva, 2007).

However, chemical control, through the use of herbicides, is limited to the direct spray of glyphosate, which is the only herbicide registered for the papaya culture in Brazil. Moreover, for not being selective to culture, it can only be applied in a targeted way without reaching the green leaves and stem parts, which hinders its implementation in the first months after transplantation (Felipe et al., 2010).

In a study conducted in a greenhouse to evaluate the selectivity of herbicides applied in pre-emergence in formosa papaya seedlings, Felipe et al. (2010) found that the herbicides ametryn, diuron, oxyfluorfen, isoxaflutole and S-metholachlor did not inhibit the leaf, stem and root dry matter 45 days after application, being selective for culture. While atrazine, sulfentrazone, trifloxysulfuron-sodium and the mixture atrazine + s-metholachlor poisoned the culture.

Researches related to weed management in papaya cultivation, either in the world or in Brazil, are still incipient. Moreover, mainly, researches aiming the selection of herbicides, among those registered for cultivations in general, with potential use in papaya crops with broadcast application are scarce. Thus, this study aimed to evaluate the selectivity and efficacy of herbicides in pre-emergence to control weeds in papaya cultivation.

Material and Methods

A field experiment was conducted between February and July 2010 with the Formosa papaya hybrid "Tainung 1" in a Haplic Cambisol (Embrapa, 2013), which chemical and physical characteristics were: pH ($CaCl_2$) = 7.2; Ca = 9.1 $cmol_c^{-1}$ dm^{-3}; Mg = 2.3 $cmol_c$ dm^{-3}; K = 0.83 $cmol_c$ dm^{-3}; Al = 0.00 $cmol_c$ dm^{-3}; P = 53 mg dm^{-3}; organic matter = 17 g dm^{-3}, clayey. During the trial implementation period the average temperature and relative humidity were 27.9 ºC and 50.5%, respectively.

The experimental design was a randomized block with four replications and seven treatments, five herbicide/herbicide mixtures were applied pre-emergence of weeds before the papaya cultivation transplant, with two more controls, one kept in clean through hoeing every 14 days and another without weed control (Table 1). The plots consist on three 6.0 m-long rows, spaced 3.0 m between rows and 60 cm between plants. The central row was considered usable area, eliminating two plants from each edge.

Table 1. Treatments performed in the test.

Treatments	Comercial name	Maker	Formulation	Dose (g ha^{-1} i.a.)
Ametryn	Gesapax 500	Syngenta	SC	1500
Diuron	Diurex Agricur 500	Agricur	SC	1500
Ametryn + Diuron	-	-	SC	1500 + 1500
Flumioxazin	Flumyzin 500	Sumitomo	WP	50
Isoxaflutole	Provence	Bayer	WG	150
Witness with weeding*	-	-	-	-
Witness without weeding	-	-	-	-

* The hoeing were performed at intervals of 15 days from transplanting.

The soil preparation was done by carrying out plowing and disking. Herbicide application was held on the day before transplantation using backpack sprayer, kept at constant pressure, equipped with bar with two nozzles and tips XR 11002, angle 110° spaced 50 cm, kept at 50 cm high from the target at a pressure 250 kPa, with spray volume 200 L ha^{-1}.

Seedlings were produced in expanded polystyrene trays containing 128 cells, using the commercial substrate type Plantmax®. The transplant was performed 22 days after emergence with about 15 cm high a day after herbicide application. Irrigations in the experiment were carried out by drip system with emitters of 1.7 L h^{-1} spaced 50 cm. The amount of water applied was determined by full replacement of crop evapotranspiration.

At 21, 42 and 63 DAA evaluations of weeds of the dry matter weight were conducted by two samples in 0.25 m² squares. Weeds were harvested at ground level, separated and grouped in monocots and dicots, and taken to an oven with forced air circulation at a temperature of 65 °C to constant weight.

At 7, 14, 21 and 28 days after application (DAA) of herbicides, visual assessments of phytotoxicity in the papaya plant were performed, using a scale from 0 to 100, where 0 represents the absence of poisoning and 100 the death of the plants. At 0, 28, 42, 56 and 72 DAA, plant height and stem diameter evaluations were performed. The plant height was measured from the vertical distance between the ground and the insertion of the youngest leaf; also, the diameter of the stem was measured at 10 cm from the ground with a caliper in five plants in the useful area of the plots.

The weeds dry matter weight data obtained were transformed into $(x + 1)^{0.5}$ and subsequently subjected to analysis of variance by F test and Duncan test at 5% probability.

Data on the toxicity of papaya plants and plant growth in both height and stem diameter, depending on the time after treatments application, were subjected to analysis of variance by F test at 5% probability, and subsequently to regression analysis. The selection of models was based on the biological explanation, the significance of the regression mean square and the parameter estimates.

Results and Discussion

The main weed that infested the experiments were benghal dayflower (*Commelina benghalensis*), joyweed (*Alternanthera tenella*), spiny amaranth (*Amarantus espinosus*), grass burr (*Cenchrus echinatus*) and Indian goosegrass (*Eleusine indica*), however, the data from the weeds dry matter were grouped into dicots and monocots. Due to low monocots infestation, there was no difference among the treatments in any of the evaluations (Table 2). While for dicots weeds, at the assessment made at 21 days after application (DAA), the lowest dry matter accumulation was observed in treatments with application of ametryn and ametryn + diuron, indicating greater controlling effectiveness.

Table 2. Weeds dry matter mass at 21, 42 and 63 days after application of herbicide (DAA).

Treatments	Dry mass g m^{-2}		
	Monocotyledon	Dicotyledonous	Total
		21 DAA	
Ametryn	(0,01) 1,0$^{n/s}$	(2,42) 1,8bc	1,83cd
Diuron	(0,08) 1,03	(8,71) 2,87b	2,89bc
Diuron + Ametryn	(0,23) 1,10	(3,63) 1,87bc	1,93cd
Flumioxazin	(0,33) 1,13	(10,98) 3,18ab	3,22bc
Isoxaflutole	(1,27) 1,40	(15,48) 3,51ab	3,80ab
Witness with weeding	(1,95) 1,55	(22,05) 4,78a	4,99a
Witness without weeding	(0) 1,00	(0) 1,00c	1,00d
CV % (transformed values)	33,41	38,64	35,45
		42 DAA	
Ametryn	(0,78) 1,28$^{n/s}$	(53,69) 6,83b	6,89b
Diuron	(43,55) 5,15	(70,21) 8,24b	10,52ab
Diuron + Ametryn	(12,24) 2,98	(94,64) 9,34ab	10,09ab
Flumioxazin	(0) 1	(149,24) 12,16a	12,16a
Isoxaflutole	(26,59) 3,80	(92,67) 9,33ab	10,57ab
Witness with weeding	(6,81) 2,36	(72,57) 9,25ab	8,69ab
Witness without weeding	(0) 1,00	(0) 1,00c	(0) 1,00c
CV % (transformed values)	108,04	26,64	27,61
		63 DAA	
Ametryn	(0) 1$^{n/s}$	(136,66) 11,50a	11,50a
Diuron	(5,38) 1,93	(206,82) 14,21a	14,40a
Diuron + Ametryn	(44,66) 5,25	(159,12) 12,61a	14,22a
Flumioxazin	(1,02) 1,31	(150,94) 12,13a	12,17a
Isoxaflutole	(0) 1,00	(144,82) 11,81a	11,81a
Witness with weeding	(0) 1,00	(192,76) 13,89a	13,89a
Witness without weeding	(0) 1,00	(0) 1,00b	(0) 1,00b
CV % (transformed values)	109,91	17,76	19,06

* Means followed by the same letter do not differ by Duncan test at 5% probability, Data were transformed by $(x + 1)^{0.5}$ and the original values are in parentheses, $^{n/s}$- non significant at 5% probability by Duncan test.

At 42 DAA, increased weeds dry mass was observed in all treatments, compared to previous assessment. However, the ametryn and diuron were more efficient to inhibit the infestation with less dry matter accumulation. Other authors also found that the treatments with ametryn and isolated diuron, or mixed with other herbicides, pre-emergence applied, provided reduction in both density and dry matter of weeds during the study period (Valochi, 2004; Correia et al., 2010).

After 63 DAA, the weeds accumulated dry mass during herbicide treatments did not differ from the control without hoeing, indicating that at that time, there was no effect of herbicides in soil and consequently showing an inefficient weed control.

The herbicides ametryne, diuron, flumioxazin and the mixture ametryn + diuron caused severe poisoning in papaya plants, leading to death (Figure 1). These results differ from those obtained by Felipe et al. (2010), that found no toxicity of those herbicides on papaya seedlings in work conducted in a greenhouse, using Oxisol from Viçosa-MG, pH 4.7 and 3.0 % organic matter. The biggest intoxication in this study is probably due to the lower sorption of herbicides in the soil because of higher pH (7.2) and lower organic matter content (17 g dm^{-3}), verified in the soil.

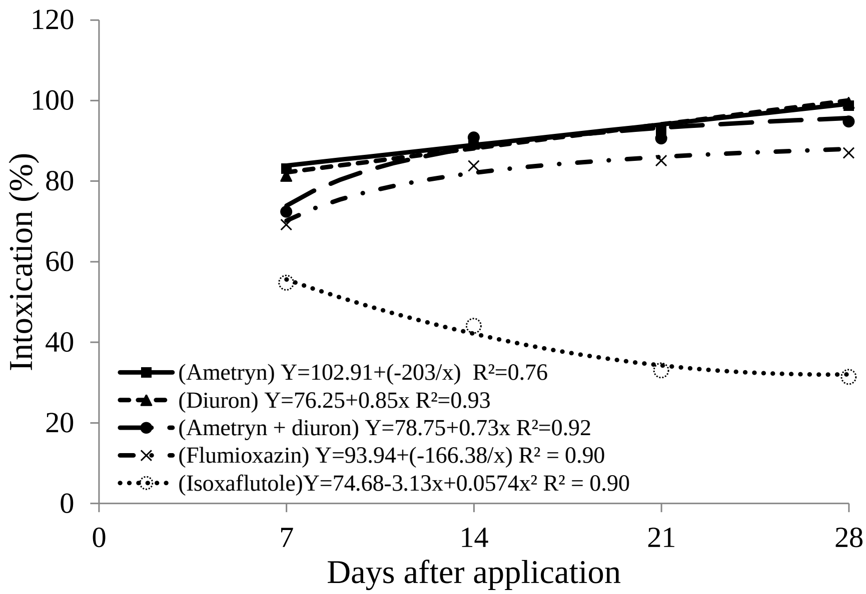

Figure 1. Papaya plants poisoning percentage due to the application of herbicides ametryn, diuron, ametryn + diuron, flumioxazin and isoxaflutole at 7, 14, 21 and 28 days after application.

The herbicide isoxaflutole caused moderate phytotoxicity in papaya plants with signs of recovery at 28 DAA (Figure 1), however, it is a herbicide which mainly controls weed grasses (Rodrigues and Almeida, 2005) and hence does not exercise good weed control and especially the dicots, as they occurred at a higher intensity (Table 2).

The sorption, mobility and persistence of herbicides in the soil are highly influenced by the physical and chemical characteristics such as pH and organic matter content **(**Andrade et al., 2010a; Andrade et al., 2010b; Andrade et al., 2010c; Melo et al., 2010). Freitas et al. (2012), assessing the behavior of the herbicide ametryne in different types of soils including Cambisol collected in Rio Grande do Norte (pH = 6.6 and 1.2% organic matter) and Oxisol from Viçosa-MG (pH = 4.7 and 3.3% organic matter), found herbicide greater leaching potential in Cambisol due to the herbicide lower sorption potential in the soil, mainly influenced by the higher pH and low organic matter content in the soil.

Diuron is also influenced by the soilphysico-chemical characteristics. In the cultivation of cotton, toponymic selectivity is presented, and when applied in soils with sandy texture it can be leached to achieve the root system of the culture, intoxicating it (Santos et al., 2011).

Considering isoxaflutole, Inoue et al. (2007), working with two soils, one sandy loam and another one clay, observed different behavior of the herbicide movement, which may be related to the organic carbon variation and, to a lesser extent, to the pH of the soil. Hence, the dissipation of the ground product at pH 7.2 is faster than at soil with pH 5.5 (Rouchaud et al. (1998).

The flumioxazin is not dissociated molecule and soil pH slightly affects its behavior (Ferrell et al., 2005). It is absorbed by soil colloids and leaching is reduced, though, it may be favored in soils with sandy texture and low organic matter content (Rodrigues and Almeida, 2005; Oliveira et al., 1999).

Given the above, it can be inferred that the soil pH above 7.0 and low concentration of organic matter, probably reduced the sorption of the herbicides ametryn, diuron and isoxaflutole (moderately), and in the case of flumioxazin that effect was caused by low organic matter content, increasing mobility of the herbicides in the soil, and poisoning papaya seedlings.

With severe intoxication causing the death of plants, height and diameter curves of papaya plant stem in treatments with herbicides ametryn, diuron, flumioxazin and e thmixture ametryn + diuron showed similar results, because they were only measured on transplantation. While the treatments with isoxaflutole, with and without hoeing presented similar height plants (Figure 2), although the weed has provided papaya plants with lower stem diameter in treatments without hoeing and with isoxaflutole application (Figure 3), it is observed that the stem diameter is the most appropriate feature to measure the degree of weed interference in papaya plants because of stimulating thin stem formation - under competition, especially by light, the plants tend to increase their growth in height, resulting in plants etiolated.

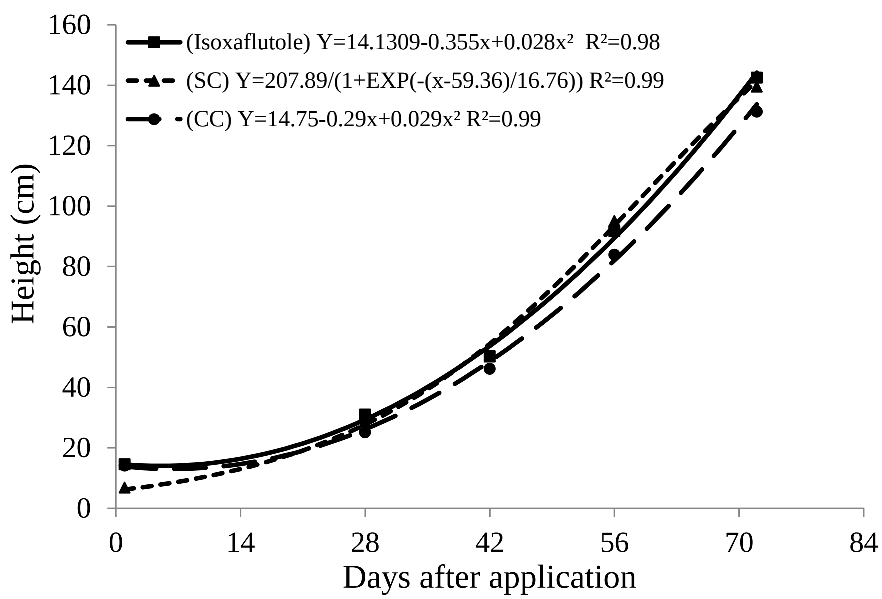

Figure 2. Papaya plant height due to treatments with hoeing (CC), without hoeing (SC) and applying the herbicide isoxaflutole, at 0, 28, 42, 56 and 72 days after application.

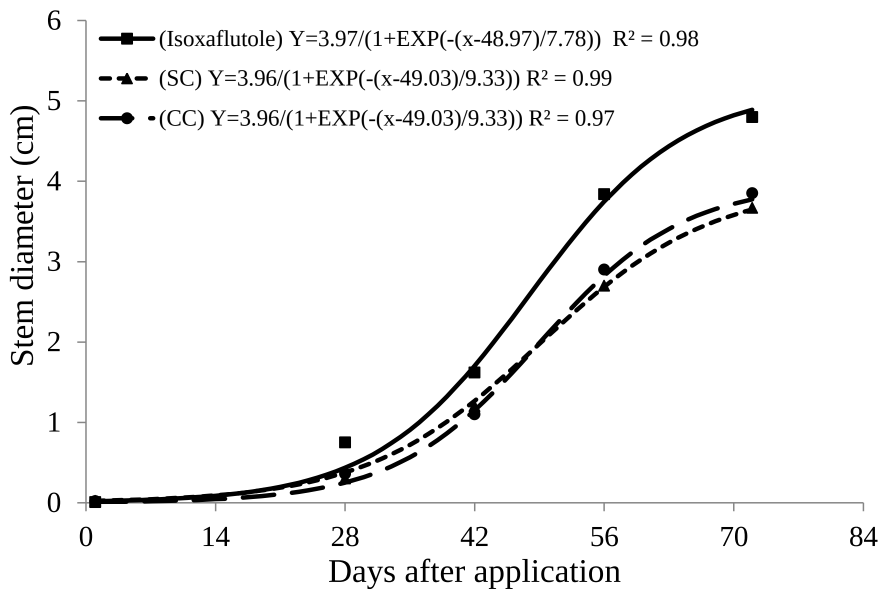

Figure 3. Diameter of papaya plant stem due to treatments with hoeing (CC), without hoeing (SC) and applying the herbicide isoxaflutole, at 0, 28, 42, 56 and 72 days after application.

Conclusions

The herbicides ametryne, diuron, flumioxazin and the mixture diuron + ametryn caused the death of papaya plants.

The isoxaflutole, although it has caused initial intoxication in papaya seedlings, allowed their recovery.

The weed interference resulted in papaya plants with smaller stem diameter, although the plant height was not influenced.

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