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Phytotoxicity of Herbicides in Seedlings of Sweet Passion Fruit

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Abstract

The culture of sweet passion fruit has been increasingly studied and exploited commercially in Brazil, with emphasis on the State of São Paulo. This is due to the high value achieved in the market of fresh fruit and be considered a food with functional properties beneficial to human health. However, the cultivation on a large scale finds some obstacles, as the control of weeds with the use of herbicides. In this sense, the objective of this work was to evaluate the phytotoxicity of seven herbicides with different mechanisms of action in seedlings of sweet passion fruit. Different variables were assessed: initial plant height (IPH) and final plant height (FPH); initial number of sheets (INS) and end number of sheets (ENS); intoxication of plants (INTO); fresh leaf mass (FLM) and dry leaf mass (DLM); fresh stem mass (FSM); dry steam mass (DSM); fresh root mass (FRM) and dry root mass (DRM) and total dry mass (TDM). Chlorimuron-ethyl (ALS inhibitor), glyphosate (EPSP synthase inhibitor), paraquat (photosystem I inhibitor) and atrazine (photosystem II inhibitor) have the higher effect on the variables analyzed, and they caused some kind of intoxication in the plants of sweet passion fruit. Conversely, haloxyfop-p-methyl (ACCase inhibitor) and fomesafen (protox inhibitor) showed a lesser effect on the sweet passion fruit plants.

Keywords: Passifloraceae, herbicides, phytotoxicity, fruticulture

1. Introduction

The passion fruit is an important culture in the scenario of Brazilian fruticulture and currently major source generating of foreign exchange for the Country. Its fruits have excellent buds features and dietary qualities (Freitas et al., 2011), being the largest part of the fruits produced in Brazil are coming species *Passiflora edulis* var. *flavicarpa*. On the other hand, the sweet passion fruit (*Passiflora alata* Curtis) is native specie to South America, especially at Brazil, whose cultivation has expanded depending on the price achieved in the market (Bernacci et al., 2003). The species *P. edulis* represents 95% of the area cultivated in the country, used both in the processing and consumption of fresh fruits, followed by sweet passion fruit *P. alata* for fresh fruits consumption (Faleiro et al., 2011).

Weed control is one of the capital requirements to provide suitable growth and establishment of passion fruit. The interference caused by weeds in orchards of passion fruit is critical in the early months after planting, since in this stage plants are smaller. Improper weed management can lead to reduced productivity and quality of passion fruit, as weeds compete against the crop for nutrients and water (Sousa et al., 2002).

Although the fruit of the sweet passion fruit has a great market potential, there are still several questions about plant nutrition, pest and disease control, post-harvest and weed management. Regarding the weed control by means of herbicides, there is still not product registration at the Ministry of Agriculture, Livestock and Supply (MAPA).

In an attempt to investigate the phytotoxic effects of herbicides applied in post-transplanting of seedlings of yellow passion fruit. Paiva et al. (2015) observed that of the 21 herbicides tested, at least four have caused reductions in height gain. These authors also observed that only the herbicides oxadiazon, fenoxaprop-ethyl, tembotrione, chlorimuron-ethyl and not harm growth and isoxaflutole not intoxicated the seedlings, being the most promising compounds for use in total area. Even though the yellow passion fruit is membership of sweet passion fruit (Passifloraceae), these results cannot be extrapolated for dealing with different species.

The phytotoxic potential of the herbicides on the passion fruit crop is a reality that has been tested by many producers. For this reason, it is important to observe the symptoms of injuries, aspects of growth and production. Therefore, the objective of this work was to evaluate the phytotoxicity of herbicides in seedlings of sweet passion fruit, considering the symptoms of intoxication and the growth of plants.

2. Material and Methods

The research was conducted in a protected environment at the Experimental Farm of the University Center of Mineiros (FELEOS-UNIFIMES), located in the municipality of Mineiros, state of Goiás, in Brazil. The substrate was composed of soil and sand of medium texture (3:1 v/v) (Table 1).

Table 1. Result of physical-chemical analysis of Dystrophic Red Latosol

Granulometry	pH	P mel.	K^+	Ca^{+2}	Mg^{+2}	Al^{+3}	H+Al	SB[1]	CEC_{Total}[2]	BS[3]	MO[4]
---------- % ---------		g dm^{-3}	----------------------------- mmol dm^{-3} ----------------------------							%	g dm^{-3}
Clay = 70	5.4	2	2.0	54	12	1	25	68	93.0	73.13	17
Silt = 14											
Sand = 16											

Note. Analysis obtained from the UNIFIMES Soil Analysis Laboratory, according to the methodology EMBRAPA (1997). [1]SB: Sum of bases. [2]CEC_{total}: Cation Exchange Capacity; [3]BS: Base saturation; [4]OM: Organic matter.

Were applied to 10 kg of fertilizer formulated 4-14-8 for a volume of 400 kg of substrate and packaged in plastic pots with capacity of 10 L. The microspray irrigation was held daily, except on days with rainfall occurrence.

The treatments consisted in the use of seven herbicides with different mechanisms of action and a control without herbicide application, as described in Table 2. The experimental design was completely randomized, with 8 treatments and five replications. Each pot represented an experimental unit, totaling 40 plots.

Table 2. Classification of herbicides and their rates applied on sweet passion fruit plants

Mechanism of action	Commercial product	Active ingredient (a.i)	Dose a.i (g ha^{-1})
ACCase Inhibitors	Verdict®	Haloxyfop-p-methyl	43.64
ALS Inhibitors	Classic®	Chlorimuron-ethyl	17.5
EPSP Synthase Inhibitors	Roundup Original®	Glyphosate	720
Photosystem I Inhibitors	Gramoxone® 200	Paraquat	2000
Photosystem II Inhibitors	Atranex® 500 SC	Atrazine	300
Carotenoid Biosynthesis Inhibitors	Gamit®	Clomazone	0.75
Inhibitors Protox	Flex®	Fomesafen	225
Control	-	-	-

The application of treatments occurred in the first half of the year 2017, the 90 days after the multiplication of stakes. We used a manual sprayer with constant pressure of 150 kPa, fitted with spray nozzle type JD-12 p. at a height of 50 cm from the target and volume of 200 L ha^{-1}.

The evaluations of plant height and number of leaves occurred at the time of application of treatments and at the end of the experiment.

The visual evaluations of intoxication of culture were made to 3; 6; 9; 12; 15; 18 and 21 days after herbicide application (DAHA), with the use of a percentile scale of notes ranging from 0 (zero) to 100 (one hundred), where, 0 indicates the absence of any injuries and 100 indicates the death of plant (SBCPD, 1995). The criteria used for the establishment of the notes were: inhibition of growth, quantity and uniformity of injury in plants, colour of leaves, leaf limb deformities and regrowth (issuance of new leaves).

After 21 DAHA, was held the last measurement of height and number of leaves, then the plants were separated into leaves and stem, and roots were washed to remove the excess of soil. The samples regarding the aerial part (leaves and stems) and roots were packed in paper bags and weighed in precision balance for determination of fresh mass. Then the samples were placed in an oven with forced air circulation at 70 °C until constant weight to determine the dry mass.

The variables analyzed were: initial plant height (cm) (IPH) and final plant height (cm) (FPH); initial number of sheets (INS) and end number of sheets (ENS); intoxication of plants (%) (INTO); fresh leaf mass (g) (FLM) and dry leaf mass (g) (DLM); fresh stem mass (g) (FSM); dry steam mass (g) (DSM); fresh root mass (g) (FRM); dry root mass (g) (DRM) and total dry mass (g) (TDM).

The data were subjected to analysis of variance and averages when significant were grouped according to Scott-Knott, the 5% probability of error, through the statistical SISVAR 5.3 program.

3. Results and Discussion

The results concerning the height initial plant (IPH) and final plant height (FPH), initial number of sheets (INS) and end number of sheets (ENS) and intoxication of plants (INTO) are shown in Table 3.

Table 3. Phytotoxic effects of different commercial herbicides in growth of sweet passion fruit plants

Herbicides	Variables of growth				
	IPH	FPH	INS	ENS	INTO
	----------------- cm	----------------	-	-	-------- % --------
Control	1.14 a	1.35 a	16.00 a	20.50 a	0.00 c
Haloxyfop-p-methyl	1.16 a	1.39 a	17.00 a	20.75 a	25.00 b
Chlorimuron-ethyl	1.08 a	1.07 a	16.00 a	11.25 b	50.00 ab
Glyphosate	1.01 a	0.93 a	16.00 a	15.50 a	25.00 b
Atrazine	1.12 a	1.14 a	16.25 a	3.00 c	80.00 a
Paraquat	1.00 a	1.24 a	15.50 a	4.75 c	80.00 a
Clomazone	1.18 a	1.34 a	17.00 a	19.25 a	35.00 ab
Fomesafen	1.10 a	1.22 a	16.25 a	19.50 a	25.00 b
CV (%)	11.63	16.05	13.59	28.33	29.38

Note. Averages constituted by the same vertical letter do not differ from each other. by Scott-Knott test, at 0.05 probability level. Initial plant height (cm) (IPH) and final plant height (cm) (FPH); initial number of sheets (INS) and end number of sheets (ENS) and intoxication of plants (%) (INTO).

The herbicides glyphosate, imazapic, metsulfuron-methyl and glufosinate-ammonium reduced plant height gain (Paiva et al., 2015). According to Polini et al. (2018) to application of herbicide glyphosate was the least selective to the tree species in its different concentrations, causing phytotoxic effects with changes in the seedlings morphology. The results of this study could help in the integrated management of weeds and contribute to the efficient herbicide use in planting forest species in the Cerrado. Although there was no significant difference between the initial and final height, the ENS was lower when used herbicides Atrazine, Paraquat and Chlorimuron-ethyl in relation to other herbicides (Figure 1).

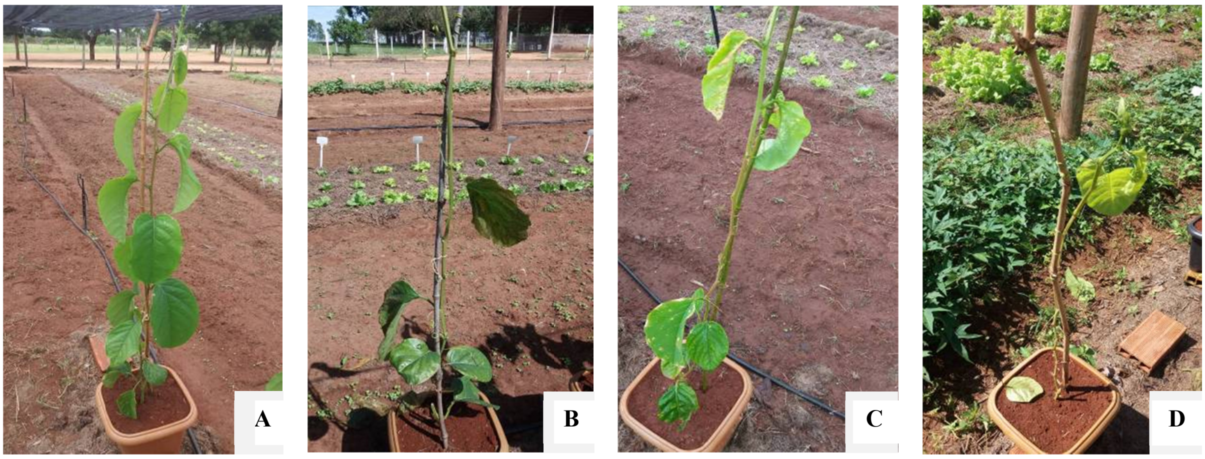

Figure 1. Imagens of phytotoxicity the herbicides: Control (A), Atrazine (B), Paraquat (C), Chlorimuron-ethyl (D)

The number of final leaves was statistically equal to the control for the herbicides: Haloxifop-p-methyl; Ghyphosate; Fomesafen and Clomazone. For Bandeira et al. (2016) the number of cassava leaves in the treatments with haloxyfop, quizalofop-P-ethyl and chlorimuron-ethyl presented similar to that of the control during assessments. In contrast, fomesafen treatments and the mixture fomesafen + quizalofop-P-ethyl, promoted initially elevated with symptoms of chlorosis and necrosis of the treated areas (leaves and of leaf turgescence, similar to the effect observed with lactofen. However, the plants showed rapid recovery.

The herbicides glifosate, imazapic, metsulfuron-methyl and amonioglufosinate have reduced the height of yellow passion fruit plants in the studies of Paiva et al. (2015). For the variable INTO when applied Atrazine (80%) and Paraquat (80%) showed higher percentage of symptoms in seedlings. In contrast, there was less intensity of intoxication when used herbicides Chlorimuron-ethyl (50%) and Clomazone (35%).

The FLM was lower when applied the herbicide Atrazine, with average value of 3.5 g of leaves per plant, arising from major injuries in seedlings and falling leaves. This value is much lower than the control presented average 80.5 g of leaves per plant. On the other hand, the herbicides which did not differ from the control were Haloxifop-p-ethyl (81.5 g), Clomazone (72.25 g) and Fomesafen (68.0 g).

The FRM decreases drastically when applied herbicides Chlorimuron-ethyl (31.75 g) and Glyphosate (30.25 g). Unlike the herbicide Clomazone which was higher than the control with average value of 106.25 g of root per plant (Table 4).

However, obtaining the DRM made it possible to check what else herbicides affect the root of seedlings in relation to control (12.87 g) was the chlorimuron-ethyl, glyphosate, atrazine and paraquat, being the lowest average value of 4.22 g root for plant. While herbicides haloxifop-p-ethyl clomazone and increased the amount of DRM, with maximum value up 14.91 g of root per plant (Table 4).

One of the herbicides used in this study, the most diminished the TDM were the Chlorimuron-ethyl, Glyphosate, Atrazine and Paraquat. And those who showed symptoms of poisoning, but did not differ from the control were Haloxifop, Clomazone and Fomesafen (Table 4). The herbicides atrazine, linuron, diuron, tebuthiuron, metribuzin and bentazon also reduced the dry leaf mass, stem and total passion fruit plants yellow (Paiva et al., 2015).

Table 4. Production of fitomass of plants sweet passion fruit after of differents herbicides

Herbicides	Variables						
	FLM	FSM	FRM	DLM	DSM	DRM	TDM
	---------- (g) ----------						
Control	80.50 a	43.25 a	87.00 c	16.84 c	8.73 a	12.87 b	38.45 a
Haloxyfop-p-methyl	81.50 a	53.00 a	101.25 b	22.56 a	12.05 a	14.91 a	49.53 a
Chlorimuron-ethyl	34.25 b	27.25 b	31.75 d	8.41 b	6.32 b	4.25 d	19.27 b
Glyphosate	49.25 b	27.75 b	30.25 d	12.79 c	6.94 b	4.22 d	23.96 b
Atrazine	3.50 c	32.75 b	82.75 c	0.86 d	5.23 b	8.34 d	14.44 b
Paraquat	30.75 b	36.00 b	50.75 b	6.49 b	6.28 b	5.11 d	19.70 b
Clomazone	72.25 a	41.75 a	106.25 a	20.05 a	10.33 a	14.36 a	44.75 a
Fomesafen	68.00 a	37.50 b	85.00 c	18.91 a	9.38 a	11.82 c	40.12 a
CV (%)	27.11	20.45	4.30	29.05	26.51	6.60	18.43

Note. Averages constituted by the same vertical letter do not differ from each other. by Scott-Knott test. at 0.05 probability level. Fresh leaf mass (g) (FLM); fresh stem mass (g) (FSM); fresh root mass (g) (FRM); dry leaf mass (g) (DLM); dry steam mass (g) (DSM); dry root mass (g) (DRM) and total dry mass (g) (TDM).

Yamada and Castro (2007) found that glyphosate causes a rapid reduction in the content of Auxin in plants through the formation of conjugated and oxidative degradation of indolilacético acid (IAA). These reports demonstrated the influence of IAA on the growth of roots, and your disability can cause malformation of blood vessels leads to SAP and roots, because of harmful doses of glyphosate, intervened in vegetable production and imbalance transport of Auxin. On the contrary, the herbicides Haloxyfop-p-methyl (14.91 g) and Clomazone (14.36 g) collaborated with the increment of roots, with values higher than control (12.87 g).

In similar work, Paiva et al. (2015) noted that no herbicide did damage the root system of plants, to assess the effects of the application of herbicides after transplanting of seedlings of yellow passion fruit.

The passion fruit can be a plant sensitive to the presence of chemicals, in this case of herbicides. Silva et al. (2007) found that there was a reduction of 38% of the dry root mass of seedlings of passion fruit, due to the residual effect of the herbicide fluazifop-p-butyl mix + fomesafen. This did not occur in other crops such as squash, cucumber and corn, demonstrating the likelihood of injury occurs in the culture of passion fruit in succession crops.

Herbicides that presented the symptoms of intoxication on the third day after the application were Paraquat (Gramoxone® 500 SC) and Atrazine (Atranex® 200). As for the other herbicides symptoms were manifested by plants only on the 6 DAA of herbicides and herbicide Haloxyfop-p-methyl (Verdict®) was the least affected passion fruit plants along the conduction of experiment (Figure 2).

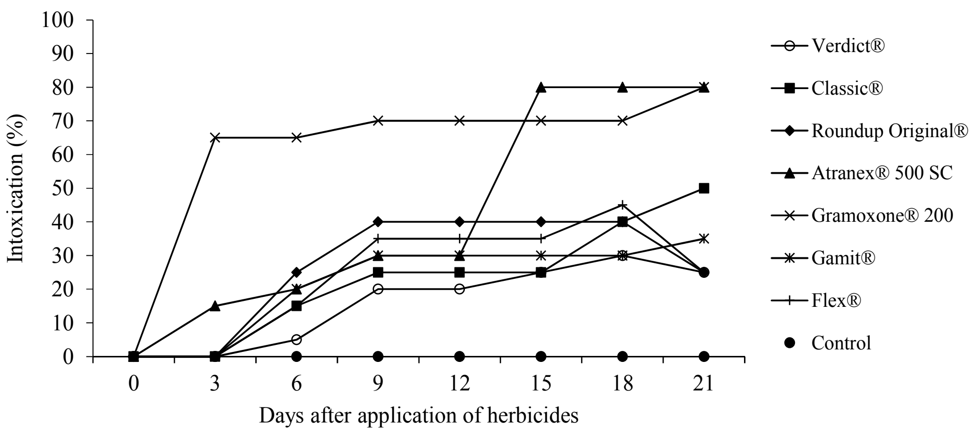

Figure 2. Percentage of intoxication by application of herbicides in sweet passion fruit seedlings in the interval 0 to 21 days after herbicide application (DAHA)

These results suggest an increase in the evaluation period of the plants and herbicide application in plants conducted in the field.

According to Wagner Júnior et al. (2008), evaluating the symptoms of phytotoxicity on culture of yellow passion fruit genotypes at different times (7, 14 and 28 days) after the application of herbicides, might note that typical glyphosate poisoning symptoms, such in chlorosis and necrosis, or death of the apices, occurred from the seventh day of application of the product. The disruption of apical growth presented reflections in the total length of yellow passion fruit plants as a result of the application of the largest doses of glyphosate at work by the same author.

Nascimento et al. (2015) evaluated the selectivity and herbicides efficiency pre-emergence applied in papaya crop. The herbicides ametrine, diuron, flumioxazin and the mixture ametryn + diuron caused the death of papaya seedlings, and isoxaflutole caused poisoning in seedlings with subsequent recovery.

With the exception of commercial products Verdict®, Glifosate® and Flex®, the other caused symptoms of poisoning by herbicides with values greater than 25% (Figure 3).

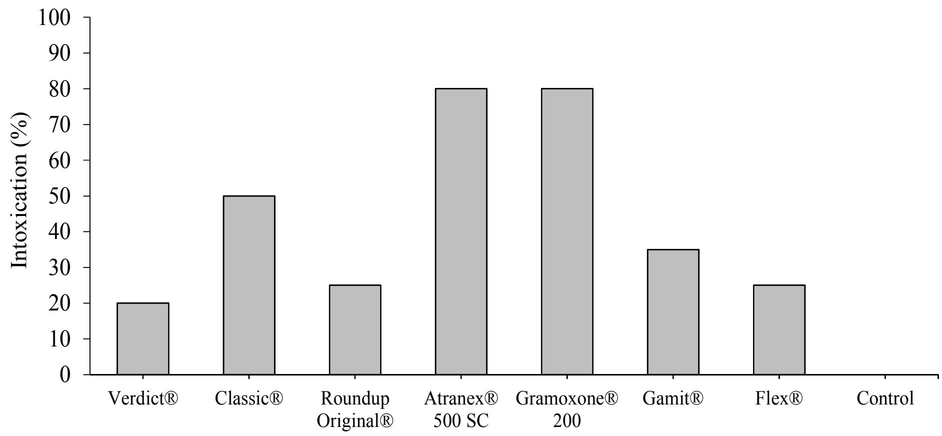

Figure 3. Percentage of intoxication by application of herbicides in sweet passion fruit plants after application of herbicides

As Paiva et al. (2015), the herbicides oxadiazon, fenoxaprop-ethyl, tembotrione, chlorimuron-ethyl and isoxaflutole, did not jeopardize the growth or intoxicate the yellow passion fruit seedlings, being the most promising for use in total area.

4. Conclusion

The herbicides Chlorimuron-ethyl, Glyphosate, Paraquat and Atrazine were the most harmful to seedlings of sweet passion fruit, causing loss of foliage and the decrease of the total dry mass of plants evaluated.

Despite the intoxication caused by herbicide Haloxyfop-p-methyl and Fomesafen, both did not differ from the control to most of the analyzed variables, including total dry mass of plants.

The results of this study could help in the integrated management of weeds and contribute to the efficient herbicide use in planting of sweet passion fruit (*P. alata*).

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