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SCIENTIFIC ARTICLE
Plant Health Defense

Selectivity of herbicides applied to Brazilian tree species at post-emergence

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ABSTRACT
The presence of weeds in silvicultural systems has been considered one of the main obstacles to the success of projects designed to recover degraded areas. The aim of this study was to evaluate the selectivity of herbicides applied at post-emergence in the initial growth of seedlings of capixingui (*Croton floribundus*), açoita-cavalo (*Luehea divaricata*), and guaritá (*Astronium graveolens*), in the municipalities of Jaboticabal and Junqueirópolis, state of São Paulo. The experimental design was completely randomized, with four replications, and the treatments consisted of herbicides (g a.i.·ha^{-1}) clethodim + phenoxaprop-p-ethyl (50 + 50), sethoxydim (184), quizalofop-p-ethyl (75), nicosulfuron (50), fluazifop-p-butyl (125), fomesafen (225), haloxyfop-methyl (48), bentazon (720), chlorimuron-ethyl (15), in addition to control without herbicide. The characteristics analyzed were: plant height increase and visual phytointoxication at 7, 14, 21, 28, 35, and 42 days after herbicide application. At the end of the experiment, the shoots of the plants were removed to assess shoot dry matter. The herbicides clethodim + fenoxaprop-p-ethyl, fluazifop-p-butyl, and quizalofop-p-ethyl showed selective potential for the species capixingui, açoita-cavalo, and guaritá. The herbicide chlorimuron-ethyl caused mild intoxication symptoms when applied to seedlings of capixingui and açoita-cavalo; also, it was not selective for the guaritá species grown in Jaboticabal. All species showed selectivity to the herbicides sethoxydim, fomesafen, haloxyfop-methyl, and nicosulfuron, as their growth and initial development were not influenced. The herbicide bentazon caused high percentages of injury to açoita-cavalo plants in both cultivation places, but it did not influence the growth and development of the species.

Keywords: ALS inhibitors; Brazil; tolerance; weed interference.

INTRODUCTION

It is estimated that Brazil has about 21 million hectares with a deficit of native vegetation in areas of permanent preservation and legal reserve (OLIVEIRA et al., 2019). For this reason, the recovery of these areas has been considered a priority, given the serious environmental damage resulting from anthropic actions on natural ecosystems (NUNES et al., 2015).

As a result, sectors of society, together with government agencies, are engaged in actions that encourage farmers to conserve and recover these degraded areas (MARQUES et al., 2019; OLIVEIRA et al., 2019). In addition, the restoration of permanent preservation areas, with conflicting use of land and implementation or adaptation of the legal reserve, will be mandatory, owing to the provisions of the new Brazilian Forest Law and the implementation of the rural environmental registry (AGUIAR et al., 2016; MARCHI et al., 2018).

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However, it is noteworthy that the implementation of projects for the recovery of degraded areas using native species is costly, because of expenses with production, planting, and management of seedlings (FARIAS et al., 2012). Implementation is a decisive stage for the success of a forestry enterprise, and one of the major precautions to be taken in this phase is weed control (BOSCARDIN et al., 2016).

The presence of weeds in silvicultural systems can cause negative interference, especially in the initial periods of the crop, owing to competition for environmental resources, which is unfavorable to the full development of the forest component (VASIC et al., 2014; ASSIS et al., 2015). The difficulty in controlling these plants has been considered one of the main obstacles to the success of projects for the recovery of degraded areas (BORGES et al., 2011).

Chemical management is an efficient and fast method for weed control when compared to manual and mechanical weeding. The use of herbicides makes it possible to manage these invasive plant species in large areas, as well as use less labor (MACHADO et al., 2013); however, whether or not this method can be adopted depends on restrictions on use by environmental agencies (PEREIRA et al., 2015).

In order to improve weed control methods in reforestation, herbicides with selective action for some agricultural crops have been used empirically (ARALDI et al., 2015). MONQUERO et al. (2011) stated that, for the use of chemical management to control these undesirable plants, further studies are needed to choose herbicides selective to the native species used in reforestation.

For the above-mentioned reasons, the objective of this study was to evaluate the selectivity of herbicides applied at post-emergence in the initial growth of Brazilian tree species: capixingui (*Croton floribundus* Spreng), açoita-cavalo (*Luehea divaricata* Mart. & Zucc.) and guaritá (*Astronium graveleons* Jacq.), in two different locations.

MATERIAL AND METHODS

The study was carried out in two distinct regions. The first experiment was conducted in Jaboticabal, state of São Paulo, located at 21°15’17”S and 48°19’20”W Gr., with an altitude of 605 m. The second experiment was carried out in Junqueirópolis, São Paulo, located at 21°30’53”S and 51°26’01”W Gr., with an altitude of 421 m.

The studied native tree species capixingui, açoita-cavalo, and guaritá were obtained by a nursery for seedling production located in Rosana, São Paulo. The experimental design was a completely randomized design with four replications and the treatments consisted of the application of nine herbicides (g a.i.·ha^{-1}): clethodim + fenoxaprop--p-ethyl ([50 + 50] + mineral oil Assist [0.5% v/v]), sethoxydim (184), quizalofop-p-ethyl (75), nicosulfuron (50), fluazifop-p-butyl (125), fomesafen (225), haloxyfop-methyl (48), bentazon (720), chlorimuron-ethyl (15), and control without herbicide.

Each experimental unit consisted of a plastic pot with a 5.0 L capacity filled with the soils of each region: a red-yellow latosol in Jaboticabal and a dystroferric red argisol in Junqueirópolis. Both soils were mixed with coconut shell-based substrate at a ratio of 3:1 (substrate: soil), in addition to 1.4 g of NPK (04-14-08) per pot. Top dressing fertilization was performed with potassium nitrate at a dose of 400 mg per experimental unit at 30 days after seedling transplanting.

In the experiment conducted in Jaboticabal, the herbicide application was performed at 60 days after transplanting seedlings with 30 to 40 cm high. In the experiment carried out in Junqueirópolis, the herbicide spraying on seedlings of native species occurred at 70 days after transplanting seedlings with 35 to 40 cm high.

The herbicide applications were performed using a backpack sprayer, CO_2-pressurized containing two flat jet nozzles (Teejet 11002VS), at a constant pressure of 200 kPa and set to deliver 200 L·ha^{-1} of the solution. Plants were maintained under a lath house covered by a shading screen, which received sprinkler irrigation and precipitation that totaled 649.5 mm from the transplant to the last data collection.

Visual evaluations of phytointoxication were carried out at 7, 14, 21, 28, 35, and 42 days after application (DAA) of herbicide through a percentage score scale, where 0 represents no visual injury caused by herbicides and 100 corresponds to plant death. Plant height was measured using a measuring tape and considering the distance from the ground to the apex of the highest plant leaf. The increment in plant height was obtained from the difference between the means observed at 42 DAA and the means observed at application time.

At the end of the evaluations (at 42 DAA), plant shoots were collected, and the dry matter was obtained by drying them in a forced circulation oven at 65 °C until constant weight. The results were submitted for analysis of variance by the F-test, and the means of the treatments were compared by the Tukey’s test at 5% probability with the aid of the statistical program SISVAR 5.3 (FERREIRA, 2011).

RESULTS AND DISCUSSION

Capixingui (*Croton floribundus*)

Jaboticabal

It was found that the application of the herbicides clethodim + fenoxaprop-p-ethyl and fluazifop-p-butyl did not promote visual injury symptoms in the seedlings of capixingui plants, in all the assessment periods. Mild symptoms of visual intoxication were found at 7 and 14 DAA with the herbicides sethoxydim and quizalofop-p-ethyl, and in the subsequent assessments, there were no visual injury symptoms until 42 DAA (Table 1).

Table 1. Percentage of intoxication of *Croton floribundus* (capixingui) plants after application of several herbicides, at different assessment times, as well as the effects of these herbicides on height increase and shoot dry matter accumulation of capixingui plants, at 42 days after application. Jaboticabal/SP

Treatment	Days after herbicide application						Height	DM[3]
	7	14	21	28	35	42	(cm)	(g)
1. clethodim + fenox[1]	0.0 c	0.0 c	0.0 e	0.0 c	0.0 d	0.0 c	11.5 ab	9.4
2. fluazifop-p-butyl	0.0 c	0.0 c	0.0 e	0.0 c	0.0 d	0.0 c	12.5 a	10.5
3. sethoxydim[2]	2.0 bc	2.2 bc	0.0 e	0.0 c	0.0 d	0.0 c	6.0 ab	12.8
4. quizalofop-p-ethyl	2.5 bc	2.2 bc	0.0 e	0.0 c	0.0 d	0.0 c	6.7 ab	13.1
5. fomesafen	11.0 a	11.5 a	13.2 a	10.7 a	6.5 b	2.2 b	13.0 a	12.3
6. haloxyfop-methyl	4.5 b	4.7 b	3.5 cd	1.7 bc	1.7 cd	0.5 c	7.0 ab	14.0
7. nicosulfuron	3.5 b	5.0 b	6.2 bc	11.2 a	9.2 a	8.5 a	4.1 b	8.0
8. bentazon	2.5 bc	2.5 bc	3.0 d	2.2 bc	1.7 cd	0.0 c	7.2 ab	10.7
9. chlorimuron-ethyl	8.0 a	8.5 a	7.0 b	4.5 b	3.5 c	1.2 bc	10.0 ab	13.5
10. Control	-	-	-	-	-	-	8.2 ab	10.9
F Treatment	29.69**	33.82**	57.46**	56.41**	37.12**	87.77**	3.51**	1.58NS
CV (%)	35.29	32.39	32.56	35.91	43.23	42.70	36.75	26.55
LSD	3.17	3.14	2.84	2.89	2.60	1.41	7.65	7.40

NS: nonsignificant; ** significant at 1%; [1]fenoxaprop-p-ethyl; [2]0.5% v/v ASSIST mineral oil was added; [3]Dry Matter. Means followed by the same lowercase letter in the column, do not differ statistically from each other, by Tukey's test ($p < 0.05$). CV: coefficient of variation; LSD: low significant difference.

In the other study, active ingredients (fomesafen, haloxyfop-methyl, nicosulfuron, bentazon, and chlorimuron-ethyl) resulted in low visual injury percentages in capixingui plants, regardless of the days that elapsed after the applications, with values that increased between 14 and 28 DAA and gradually decreased until 42 DAA (Table 1). Contrary to these findings, MONQUERO et al. (2016) reported that underdoses of the herbicides glyphosate, 2,4-D, and picloram, in addition to the association glyphosate + 2,4-D, caused severe injury symptoms (greater than 80%) in *C. floribundus* plants. This result shows that these herbicides must be carefully applied in reforestation areas with this species.

Shoot dry matter of capixingui plants was not affected by any of the study herbicides. However, the application of the herbicide nicosulfuron resulted in the highest levels of injury as of 28 DAA, and in the greatest reduction in seedling height increase for *C. floribundus* (Table 1).

Nicosulfuron is a systemic herbicide, from the chemical group of sulfonylureas acetolactate synthase (ALS) inhibitors, which stands out in the control of monocotyledonous and some eudicotyledonous weeds (MENEZES et al., 2012). ALS-inhibiting herbicides particularly inhibit the synthesis of ALS, a common enzyme in the biosynthesis of the three amino acids in the aliphatic chain: valine, leucine, and isoleucine. This inhibition interrupts protein synthesis, which interferes with DNA synthesis and cell growth (MARINHO et al., 2018), directly affecting plant height, as shown in the results found in this research for the species *C. floribundus*.

When assessing the sensitivity of the species *Dipteryx alata* Vogel to the herbicide nicosulfuron, SILVA et al. (2020) concluded that the herbicide altered the photosynthetic apparatus and the enzymatic metabolism of the species, with reductions in physiological characteristics. Their finding suggests that native tree species may be highly sensitive to this herbicide.

Junqueirópolis

For the experiment conducted in the city of Junqueirópolis, it was found that the herbicides sethoxydim, nicosulfuron, and chlorimuron-ethyl caused mild visual intoxication in all assessment periods, since the values showed a low increase in subsequent assessments, with gradual decrease until 42 DAA. The other herbicides did not cause visual intoxication symptoms in capixingui plants, regardless of the assessment period (Table 2).

When studying the tolerance of African mahogany plants (Khaya ivorensis A. Chev) and Australian red cedar (*Toona ciliata* M. Roemer) to herbicides, BRIGHENTI; MULLER (2014) also found that the herbicides nicosulfuron and chlorimuron--ethyl caused mild symptoms of phytotoxicity in African mahogany plants. However, the researchers also reported that, when these herbicides were applied in the Australian cedar, they could find high levels of visual injury; therefore, they underscored that forest species, whether exotic or native, have to be carefully selected for reforestation areas, especially as far as weed control is concerned. Importantly, OLIVEIRA JÚNIOR et al. (2011) stated that selectivity to herbicides can be obtained through physiological and morphological differences between plant species.

Table 2. Percentage of intoxication of *Croton floribundus* (capixingui) plants after application of several herbicides, at different assessment times, as well as the effects of these herbicides on height increase and shoot dry matter accumulation of capixingui plants, at 42 days after application. Junqueirópolis/SP

Treatment	Days after herbicide application						Height	DM/3
	7	14	21	28	35	42	(cm)	(g)
1. clethodim + fenox/1	0.0 d	0.0 d	0.0 c	0.0 c	0.0 d	0.0 c	6.4	14.1 ab
2. fluazifop-p-butyl	0.0 d	0.0 d	0.0 c	0.0 c	0.0 d	0.0 c	9.0	14.5 ab
3. sethoxydim/2	11.0 a	11.5 a	13.2 a	10.7 a	6.5 b	2.2 b	7.8	8.7 b
4. quizalofop-p-ethyl	0.0 d	0.0 d	0.0 c	0.0 c	0.0 d	0.0 c	9.1	15.7 ab
5. fomesafen	0.0 d	0.0 d	0.0 c	0.0 c	0.0 d	0.0 c	5.5	22.5 a
6. haloxyfop-methyl	0.0 d	0.0 d	0.0 c	0.0 c	0.0 d	0.0 c	7.5	7.0 b
7. nicosulfuron	3.5 c	5.0 c	6.2 b	11.2 a	9.2 a	8.5 a	6.0	11.2 ab
8. bentazon	0.0 d	0.0 d	0.0 c	0.0 c	0.0 d	0.0 c	4.3	12.2 ab
9. chlorimuron-ethyl	8.0 b	8.5 b	7.0 b	4.5 b	3.5 c	1.2 b	11.1	8.9 b
10. Control	-	-	-	-	-	-	6.9	9.4 b
F Treatment	82.76**	216.07**	128.49**	110.61**	90.51**	130.59**	1.03NS	3.38**
CV (%)	36.91	21.90	28.86	31.00	34.55	36.79	53.67	39.74
LSD	2.19	1.44	2.02	2.17	1.75	1.16	9.57	11.94

NS: nonsignificant; ** significant at 1%; /1fenoxaprop-p-ethyl; /20.5% v/v ASSIST mineral oil was added; /3Dry matter. Means followed by the same lowercase letter in the column, do not differ statistically from each other, by Tukey's test ($p < 0.05$). CV: coefficient of variation; LSD: low significant difference.

When evaluating the action of herbicides under the biometric parameters of seedlings, it was found that plant height increase was not affected by the application of the tested herbicides. However, there was a high increase in shoot dry matter accumulation in the treatment with the herbicide fomesafen, when compared to the control. In addition, other herbicides did not influence dry matter accumulation in the capixingui plants (Table 2).

Importantly, although the results for the increase in the height of the *C. floribundus* plants were not significantly different, such increase was smaller after the application of the herbicide fomesafen. This result contradicts the increase in shoot dry matter accumulation caused by the same herbicide. For this reason, it can be inferred that the nutritional reserves of the plants of capixingui were supposedly destined for the production of leaves and increase of the leaf area. It is known that, since all herbicides act in crucial pathways or processes for plants in an inhibitory or stimulatory manner, doses of any herbicide can modulate plant composition (BRITO et al., 2018).

Açoita-cavalo (*Luehea divaricata*)

Jaboticabal

The herbicides fomesafen, nicosulfuron and chlorimuron-ethyl caused slight injuries in seedlings of *L. divaricata* in all assessment periods, with values that were increased in the subsequent assessments (14, 21, 28, and 35 DAA) and decreased at 42 DAA. The herbicide bentazon showed the highest percentages of injury to plants in all assessment periods, with values that were considered to be high, especially at 28 DAA, in which there was 53.3% of visual phytointoxication. In the other study, herbicides did not cause injury symptoms in the açoita-cavalo plants (Table 3).

The herbicide bentazon, from the chemical group of benzothiadiazinones (inhibitors of photosystem II), is absorbed mainly by leaves and green tissues, reducing the electron transport chain by up to 80%, a few hours after application in sensitive species (MACEDO et al., 2008). However, ARALDI et al. (2015) stated that, although the plants of the guanandi tree species (*Calophyllum brasiliense*) showed symptoms of visual intoxication 24 h after the application of the herbicide bentazon, there was a gradual recovery of photosynthetic inhibition. This is indicative that, unlike other herbicides inhibiting photosystem II, bentazon does not cause substantial changes in thylakoids, which corroborates the results found in this research.

Table 3. Percentage of intoxication of *Luehea divaricata* (açoita-cavalo) plants after application of several herbicides, at different assessment times, as well as the effects of these herbicides on height increase and shoot dry matter accumulation of açoita-cavalo plants, at 42 days after application. Jaboticabal/SP

Treatment	Days after herbicide application						Height	DM/3
	7	14	21	28	35	42	(cm)	(g)
1. clethodim + fenox/1	0.0 c	0.0 d	0.0 d	0.0 d	0.0 d	0.0 d	15.0	15.0
2. fluazifop-p-butyl	0.0 c	0.0 d	0.0 d	0.0 d	0.0 d	0.0 d	14.7	15.8
3. sethoxydim/2	0.0 c	0.0 d	0.0 d	0.0 d	0.0 d	0.0 d	17.2	16.4
4. quizalofop-p-ethyl	0.0 c	0.0 d	0.0 d	0.0 d	0.0 d	0.0 d	13.7	17.8
5. fomesafen	15.0 a	18.0 b	17.0 b	12.2 c	9.5 c	7.0 c	20.7	18.0
6. haloxyfop-methyl	0.0 c	0.0 d	0.0 d	0.0 d	0.0 d	0.0 d	18.5	18.4
7. nicosulfuron	10.0 b	11.0 c	11.5 c	15.5 b	16.0 b	14.7 b	5.0	10.7
8. bentazon	17.7 a	40.7 a	49.2 a	53.5 a	45.7 a	23.5 a	13.7	10.8
9. chlorimuron-ethyl	10.5 b	9.5 c	10.0 c	9.7 c	7.2 c	4.5 cd	14.0	19.2
10. Control	-	-	-	-	-	-	16.0	16.4
F Treatment	86.73**	119.13**	1188.71**	829.66**	336.51**	78.71**	0.91NS	1.91NS
CV (%)	26.77	28.47	9.61	11.96	18.78	34.24	58.41	26.97
LSD	3.76	5.96	2.23	2.87	3.89	4.50	20.95	10.34

NS: nonsignificant; ** significant at 1%; /1fenoxaprop-p-ethyl; /20.5% v/v ASSIST mineral oil was added; /3Dry matter. Means followed by the same lowercase letter in the column, do not differ statistically from each other, by Tukey's test ($p < 0.05$). CV: coefficient of variation; LSD: low significant difference.

It is noteworthy that, although the herbicide bentazon caused intense visual injury rates, there was no inhibition of growth and development of *L. divaricata* (Table 3). According to RODRIGUES; ALMEIDA (2011), the selectivity of bentazon is because it is rapidly metabolized by tolerant plants into nontoxic forms, forming a glucosyl radical, which is what probably occurred in this species.

It was found that the other tested herbicides also did not influence the growth parameters evaluated for this tree species, indicating an initial selectivity for all herbicides in the plants of that species (Table 3).

Junqueirópolis

The herbicides fomesafen, nicosulfuron, bentazon and chlorimuron-ethyl caused visual intoxication in the açoita--cavalo plants grown in Junqueirópolis, regardless of the assessment period. Notably, the herbicide bentazon caused the highest rates of intoxication, which was more intense at 28 DAA (Table 4). This result is similar to the one found in the experiment conducted in Jaboticabal (Table 3). For the other herbicides, no injury symptoms were found in *L. divaricata* in the assessment periods (Table 4).

Plant height increase and shoot dry matter accumulation were not negatively affected during the experimental period by any of the tested herbicides (Table 4). Similar results were found by OLIVEIRA et al. (2019); when evaluating the selectivity of the same herbicides for the species garapeira (Apuleia leiocarpa), they did not find significant contrasts between the tested herbicides and the control without application. MONQUERO et al. (2011) also found the existence of selectivity in plants of L divaricata with the application of another herbicide, namely sulfentrazone, which was not tested in the present research.

Table 4. Percentage of intoxication of *Luehea divaricata* (açoita-cavalo) plants after application of several herbicides, at different assessment times, as well as the effects of these herbicides on height increase and shoot dry matter accumulation of açoita-cavalo plants, at 42 days after application. Junqueirópolis/SP

Treatment	Days after herbicide application						Height	DM/3
	7	14	21	28	35	42	(cm)	(g)
1. clethodim + fenox/1	0.0 c	0.0 d	0.0 e	0.0 e	0.0 d	0.0 c	6.0	16.1
2. fluazifop-p-butyl	0.0 c	0.0 d	0.0 e	0.0 e	0.0 d	0.0 c	2.6	12.5
3. sethoxydim/2	0.0 c	0.0 d	0.0 e	0.0 e	0.0 d	0.0 c	5.7	15.2
4. quizalofop-p-ethyl	0.0 c	0.0 d	0.0 e	0.0 e	0.0 d	0.0 c	3.5	9.3
5. fomesafen	12.0 a	15.0 b	14.0 b	9.2 c	6.5 c	4.0 c	3.1	14.8
6. haloxyfop-methyl	0.0 c	0.0 d	0.0 e	0.0 e	0.0 d	0.0 c	3.4	10.7
7. nicosulfuron	8.0 b	8.0 c	8.5 c	12.5 b	13.0 b	11.7 b	0.9	16.6
8. bentazon	12.7 a	35.7 a	44.2 a	48.5 a	40.7 a	18.5 a	4.8	12.6
9. chlorimuron-ethyl	6.5 b	5.5 cd	6.0 d	5.7 d	3.2 cd	0.7 c	2.4	13.3
10. Control	-	-	-	-	-	-	0.9	8.6
F Treatment	49.61**	90.55**	951.68**	678.54**	267.09**	51.54**	1.01NS	1.08NS
CV (%)	35.78	35.12	11.60	14.32	23.22	48.10	105.37	41.08
LSD	3.71	5.96	2.23	2.87	3.89	4.45	8.55	12.89

NS: nonsignificant; ** significant at 1%; /1fenoxaprop-p-ethyl; /20.5% v/v ASSIST mineral oil was added; /3Dry matter. Means followed by the same lowercase letter in the column, do not differ statistically from each other, by Tukey's test ($p < 0.05$). CV: coefficient of variation; LSD: low significant difference.

Guaritá (*Astronium graveleons*)

Jaboticabal

It was found that the herbicides fomesafen, haloxyfop-methyl, bentazon, chlorimuron-ethyl, and nicosulfuron caused mild visual injuries in all the assessment periods after application (Table 5). The visual intoxication caused by the use of fomesafen was characterized by leaf wilting and chlorosis, a typical symptom of this molecule. However, one of the characteristics of this herbicide is the presence of initial visual symptoms of intoxication, with subsequent recovery of these symptoms, without affecting the development of tree species (SILVA et al., 2014).

Table 5. Percentage of intoxication of *Astronium graveleons* (guaritá) plants after application of several herbicides, at different assessment times, as well as the effects of these herbicides on height increase and shoot dry matter accumulation of guaritá plants, at 42 days after application. Jaboticabal/SP

Treatment	Days after herbicide application						Height	DM/3
	7	14	21	28	35	42	(cm)	(g)
1. clethodim + fenox/1	0.0 d	0.0 c	0.0 b	0.0 b	0.0 b	0.0	12.0 ab	7.8
2. fluazifop-p-butyl	0.0 d	0.0 c	0.0 b	0.0 b	0.0 b	0.0	11.0 ab	6.7
3. sethoxydim/2	0.0 d	0.0 c	0.0 b	0.0 b	0.0 b	0.0	12.5 ab	7.4
4. quizalofop-p-ethyl	0.0 d	0.0 c	0.0 b	0.0 b	0.0 b	0.0	12.2 ab	8.7
5. fomesafen	5.2 a	5.7 a	4.5 a	3.0 ab	1.7 ab	0.7	15.7 a	8.0
6. haloxyfop-methyl	2.0 bc	1.5 bc	2.0 ab	1.0 b	1.0 b	0.0	14.5 a	7.8
7. nicosulfuron	0.0 d	3.0 b	3.7 a	4.5 a	2.0 ab	0.7	13.7 a	6.2
8. bentazon	3.2 b	3.5 ab	4.5 a	5.0 a	5.0 a	2.0	14.0 a	7.7
9. chlorimuron-ethyl	0.7 cd	1.5 bc	2.7 ab	2.5 ab	2.2 ab	1.0	7.0 b	7.9
10. Control	-	-	-	-	-	-	14.5 a	9.4
F Treatment	23.78**	12.45**	8.75**	8.58**	5.38**	2.68*	3.33**	0.42NS
CV (%)	62.06	67.90	69.63	78.06	107.52	169.96	21.24	36.04
LSD	1.84	2.73	3.22	3.30	3.41	2.02	6.52	6.76

NS: nonsignificant; ** significant at 1%; /1fenoxaprop-p-ethyl; /20.5% v/v ASSIST mineral oil was added; /3Dry matter. Means followed by the same lowercase letter in the column, do not differ statistically from each other, by Tukey's test ($p < 0.05$). CV: coefficient of variation; LSD: low significant difference.

Notably, plant height increase was negatively affected only by the application of the herbicide chlorimuron-ethyl, when compared to the control. Shoot dry matter accumulation of guaritá plants was not influenced by the use of herbicides (Table 5).

It should be noted that some native tree species may show mild symptoms of intoxication after herbicide application. However, once the product has been deactivated, development is back to normal, with no deleterious results for the affected plant species (OLIVEIRA et al., 2019). This may explain the injuries caused by some herbicides that, however, did not hinder the growth and development of guaritá seedlings.

Junqueirópolis

The guaritá plants grown in Junqueirópolis did not present any percentage of visual intoxication caused by the application of the herbicides in all the assessment periods. Importantly, there was no significant reduction in plant height increase when the herbicides were applied. However, even though there were no significant contrasts between the treatments and the control, it is noteworthy that the herbicide nicosulfuron led to the largest increase for this variable, with a value of 15.5 cm in height at 42 DAA (Table 6). These results were different in comparison to those of Jaboticabal, for the herbicide chlorimuron ethyl (Table 5). The reason is assumed to be the differences in the environmental conditions of the two locations.

Table 6. Effects of several herbicides on height increase and shoot dry matter accumulation of *Astronium graveleons* (guaritá) plants, at 42 days after application. Junqueirópolis/SP

Treatments	Height (cm)		Dry Matter (g)
1. clethodim + fenoxaprop-p-ethyl	4.3	ab	11.4
2. fluazifop-p-butyl	3.4	b	14.1
3. sethoxydim[/1]	5.3	ab	15.5
4. quizalofop-p-ethyl	2.7	b	12.0
5. fomesafen	3.1	b	14.0
6. haloxyfop-methyl	7.7	ab	14.0
7. nicosulfuron	15.5	a	12.1
8. bentazon	4.6	ab	15.0
9. chlorimuron-ethyl	3.6	b	9.9
10. Control	6.9	ab	11.7
F Treatment	2.37*		0.34[NS]
CV (%)	85.43		46.93
LSD	11.89		14.73

NS: Nonsignificant; ** significant at 1%; [/1]0.5% v/v ASSIST mineral oil was added. Means followed by the same lowercase letter in the column, do not differ statistically from each other, by Tukey's test ($p < 0.05$). CV: coefficient of variation; LSD: low significant difference.

CONCLUSIONS

The herbicides clethodim + fenoxaprop-p-ethyl, fluazifop-p-butyl, and quizalofop-p-ethyl showed selective potential for the species capixingui, açoita-cavalo, and guaritá and, therefore, they can be recommended for weed control in reforestation areas with native species, regardless of cultivation site.

The herbicide chlorimuron-ethyl caused mild intoxication symptoms when applied to seedlings of the capixingui and açoita-cavalo species; however, it was not selective for the guaritá species grown in Jaboticabal, thus showing a local effect.

Although all species evaluated in this study show symptoms of mild intoxication after the application of the herbicides sethoxydim, fomesafen, haloxyfop-methyl, and nicosulfuron, such species were considered to show selectivity to these herbicides, as their growth and initial development were not influenced, regardless of cultivation site.

The herbicide bentazon caused the highest percentages of injury to açoita-cavalo plants in both cultivation sites and all assessment periods, with values considered to be high. However, there was no inhibition of the growth and development of *L. divaricata*; thus, it can be recommended for application at post-emergence of native tree plants.

AUTHORS' CONTRIBUTIONS

Conceptualization: Oliveira, L.; Marques, R.F.; Silva Junior, A.C.; Marchi, S.R. **Data curation:** Oliveira, L.; Marques, R.F.; Silva Junior, A.C. **Formal analysis:** Oliveira, L.; Marques, R.F.; Silva Junior, A.C. **Project administration:** Marchi, S.R.; Martins, D. **Resources, Software:** Marchi, S.R.; Martins, D. **Writing – original draft:** Marques, R.F.; Martins, D. **Writing – review & editing:** Marques, R.F.; Martins, D.

AVAILABILITY OF DATA AND MATERIAL

The datasets generated and/or analyzed during the current study are available in the UNESP repository (https://repositorio.unesp.br/handle/11449/153866).

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CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

ETHICAL APPROVAL

Not applicable.

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