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Effect of pre-emergent graminicide herbicides on germination and early development of native species

Efeito de herbicidas graminicidas pré-emergentes sobre a germinação e o desenvolvimento inicial de espécies nativas

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Abstract

The occurrence of weeds has been the main obstacle to vegetation recovery in Cerrado areas unduly occupied by agricultural and livestock activities. This study evaluates the effect of different pre-emergent herbicides on the emergence, survival, and early development of seedlings of the native species jatobá (*Hymenaea stigonocarpa*), urucum (*Bixa orellana*), dry flour (*Albizia hasslerii*), and white jurema (*Mimosa interrupta*). The experiment was carried out under greenhouse conditions in a completely randomized experimental design with five replicates, where the treatments were constituted by herbicides: isoxaflutole, applied at the doses of 100, 200, and 300 g ai ha^{-1}; pendimethalin, at 500, 1000, and 4000 g ai ha^{-1}; and trifluralin, at 600, 1200, and 2400 g ai ha^{-1}; in addition to a control treatment, without the application of herbicides. Herbicide phytotoxicity was evaluated at 35 days after emergence for the number of emerged seedlings, number of leaves per seedling, seedling height and diameter, and root and shoot dry weight. With the results obtained, it is possible to affirm that under the conditions of the experiment, all the herbicides and doses used did not affect the emergence and early development of seedlings of species *H. stigonocarpa* and *B. orellana*. For species *A. hasslerii*, the dose of 300 g ai ha^{-1} of herbicide isoxaflutole was not selective. All doses of the herbicide trifluralin showed selectivity for species *M. interrupta*.

Additional keywords: isoxaflutole; pendimethalin; selectivity; trifluralin.

Resumo

A ocorrência de plantas daninhas tem representado a principal barreira para a recuperação da cobertura vegetal de áreas do Cerrado, indevidamente ocupadas pela exploração agropecuária. O presente trabalho teve o objetivo de avaliar o efeito de diferentes herbicidas pré-emergentes sobre a emergência, sobrevivência e desenvolvimento inicial de plântulas das espécies nativas jatobá (*Hymenaea stigonocarpa*), urucum (*Bixa orellana*), farinha-seca (*Albizia hasslerii*) e jurema-branca (*Mimosa interrupta*). O experimento foi instalado em condições de estufa agrícola, no delineamento experimental inteiramente casualizado, com cinco repetições, sendo os tratamentos constituídos pelos herbicidas: isoxaflutole aplicado nas doses de 100, 200 e 300 g ia ha^{-1}; pendimentalim aplicado nas doses de 500, 1.000 e 4.000 g ia ha^{-1} e pelo herbicida trifluralina aplicado nas doses de 600, 1.200 e 2.400 g ia ha^{-1}, além da testemunha, sem a aplicação de herbicidas. A fitotoxidade dos herbicidas foi avaliada aos 35 dias após a emergência, quanto ao número de plântulas emergidas, número de folhas por plântula, altura e diâmetro do coleto das plântulas e matéria seca de raiz e da parte aérea. Com os resultados obtidos, é possível afirmar, nas condições em que o experimento foi conduzido, que todos os herbicidas e as doses utilizadas não prejudicaram a emergência e o desenvolvimento inicial de plântulas das espécies *H. stigonocarpa* e *B. orellana*. Para a espécie *A. hasslerii,* a dose de 300 g ia ha^{-1} do herbicida isoxaflutole não foi seletiva. Todas as doses do herbicida trifluralina apresentaram seletividade para a espécie *M. interrupta*.

Palavras-chave adicionais: isoxaflutole; pendimentalim; seletividade; trifluralina.

Introduction

The occupation of ecosystems for agribusiness development suppressing plant growth is cause for great concern, especially regarding the occupation and deforestation of the Brazilian Cerrado (Silva et al., 2015). This expansion occurs mainly in areas of dense vegetation and flat relief, favoring the advance of mechanized agriculture and extensive cattle raising (Rocha et al., 2011). Approximately 53% of the 204 million hectares of this biome are estimated to have already been altered (Beuchle et al., 2015), with an average of 54 million hectares being converted to pasture and about 21.5 million hectares transformed by agriculture (Sano et al., 2010).

After several preservation measures, societal pressure, and financial incentives to rural producers, the demand for forest restoration intensified (Borges et al., 2011). Currently, the recovery of degraded areas has been considered a priority, given the serious environmental damage caused by anthropic actions on natural ecosystems (Nunes et al., 2015). In addition, restoration of permanent preservation areas (PPAs) with conflicting land use, and the implementation or adaptation of Legal Reserve will be mandatory due to the term of the new Brazilian Forest Law and the implementation of the Rural Environmental Registry (Aguiar et al., 2016).

However, implementation of projects to recover degraded areas using native species is expensive due to the costs of production, planting, and seedling management (Farias et al., 2012). Deployment is a decisive step for the success of a forestry enterprise; among the cautions to be taken during this phase, weed control stands out (Boscardin et al., 2016). The difficulty of controlling these plants has been considered as one of the main obstacles to the successful recovery of degraded areas (Borges et al., 2011).

When the areas intended for vegetation recovery are surrounded by pastures, there is a tendency for the clearings formed between forest structures to be quickly populated by exotic grasses, thus delaying regeneration by native species (Moraes Neto et al., 2010). The use of herbicides, coupled with other methods, may represent a viable alternative for weed control in recovery areas, but it is important to emphasize that the adoption of this method is related to use restrictions by environmental agencies or state enterprises (Resende & Leles, 2017).

Aiming to improve weed control methods in reforestation, herbicides selective for some agricultural crops have been used empirically (Araldi et al., 2015). Notwithstanding, the impacts of these herbicides on the diversity of the native plant community have been demonstrated in only a limited number of studies and therefore deserve more attention on risk assessment (Boutin et al., 2012). It should also be noted that the few articles found addressed the selectivity of herbicides applied in post-emergence of native species.

In view of the above, this work assesses the selectivity of different doses of pre-emergent herbicides isoxaflutole, pendimethalin, and trifluralin in the emergence, survival, and early development of seedlings of the native species jatobá (*Hymenaea stigonocarpa* Mart. Ex Hayne), urucum (*Bixa orellana* L.), dry flour (*Albizia hasslerii* (Chodat) Burr.), and white jurema (*Mimosa interrupta* Benth).

Materials and methods

The experimental phase of the present research was conducted under greenhouse conditions, at the following geographic coordinates: 15º52'29'' S and 52º18'35'' W. According to the Köppen classification (1948), the climate is type Aw.

Seeds of native species (Table 1) were provided by a nongovernmental organization called Instituto Socioambiental (ISA), being manually collected in forest remnants by quilombola communities, indigenous communities, and rural settlers. No germination test was performed and seeds were not scarified. Sowing was done directly on the substrate, in which ten seeds were deposited to guarantee the emergence of at least one seedling per pot. Each species was studied individually. All emerged seedlings were maintained during the experimental period, and no thinning was performed.

The soil used as substrate was collected in the arable layer of a dystrophic Red Latosol with sandy loam texture, being dried and sieved for the removal of plant remains. Soil samples were collected and analyzed in laboratory, and the chemical and physical characteristics are presented in Table 2. No correction was made for soil fertility and acidity, and the substrate was packed in 1.0 kg plastic pots. Irrigation was performed daily in sufficient quantity to maintain soil moisture at field capacity without consequent loss of water due to runoff. Mean minimum and maximum daily temperatures inside the greenhouse during the experiment were 18 ºC and 35 ºC, respectively.

Table 1 - Relation of the native species and weight estimation of 1,000 seeds.

Specie	Family	Name	1,000 seeds (g)
H. stigonocarpa	Caesalpinaceae	Jatobá do Cerrado	3125
B. orellana	Bixaceae	Urucum	23.3
A. hasslerii	Mimosaceae	Dry Flour	27.8
M. interrupta	Mimosaceae	White Jurema	45.5

Table 2 – Chemical and granulometric characterization of the soil.

pH	P-resin	K	Ca	Mg	Al+H	V	M.O
$CaCl_2$	(mg dm^{-3})	------------------- (mmol$_c$ dm^{-3}) --------------------				(%)	(g dm^{-3})
4.8	4.0	3.1	18.0	6.0	34.0	44.6	22.0

Granulometry (g kg^{-1})		
Sand	Silt	Clay
706	85	209

A completely randomized experimental design was used, with five replicates, where each pot was considered an experimental unit. Experimental treatments consisted of the herbicide isoxaflutole, applied at 100, 200, and 300 g ai ha^{-1}; herbicide pendimethalin, at 500, 1000, and 4000 g ai ha^{-1}; and herbicide trifluralin, applied at 600, 1200, and 2400 g ai ha^{-1}; in addition to a control treatment, without the application of herbicides. Herbicide doses considered the minimum dose, and two, three (in the case of isoxaflutole), and four times (in the case of trifluralin and pendimethalin) the average dose recommended for the various crops according to the package inserts supplied by the respective manufacturers.

Herbicide treatments were applied in pre-emergence with the aid of a CO_2-pressurized sprayer equipped with a spray bar with four 110015 VS flat-fan nozzles, spaced 50 cm apart, 50 cm away from the target, and calibrated at 35 psi, with syrup consumption equivalent to 200 L ha^{-1}.

Seed emergence was evaluated daily until seedling emergence ceased, which corresponded to the experimental period of 35 days. Seedlings were evaluated at the end of the experimental period for the number of emerged seedlings, number of leaves per seedling, and seedling height and stem diameter at soil level.

Seedling shoots were cut and all material obtained was packed in paper bags. Next, the roots were carefully separated from the soil with the aid of water jets, and the entire root system also packed in paper bags. Shoot and root samples were maintained in a greenhouse with forced air circulation and constant temperature of 65 °C for 72 hours, after which total dry weight was obtained with the aid of a scale with an accuracy of 0.001 g. Subsequently, mean root and shoot dry weight were calculated as a function of the number of seedlings evaluated.

The values obtained for all variables were subjected to analysis of variance by the F test using the statistical program AgroEstat (Barbosa & Maldonado Jr., 2015). The means of treatments were compared by the Scott-Knott test at 5% probability ($p > 0.05$).

Results and discussion

All the herbicides studied did not affect the number of seedlings, number of leaves, seedling height, stem diameter, and root and shoot dry weight, regardless of the dose used. All values obtained for these variables were statistically similar ($p > 0.05$) to the values obtained in the control (Table 3).

Table 3 - Effect of herbicides and doses on the number of seedlings, number of leaves, height of seedlings (cm), stem diameter (mm) and root and shoot dry mass (g) of *H. stigonocarpa.*

Treatment	Number		Height	Diameter	Dry mass (g)	
	Seedlings	Leaves	(cm)	(mm)	Root	Shoot
Isoxaflutole 100	1.8	6.5	25.1	0.33	1.32	2.39
Isoxaflutole 200	2.2	6.1	23.2	0.33	1.57	2.33
Isoxaflutole 300	2.0	7.1	24.2	0.31	1.67	2.44
Pendimentalim 500	2.2	7.1	22.5	0.33	1.45	2.51
Pendimentalim 1000	2.2	5.3	21.3	0.37	1.76	2.38
Pendimentalim 4000	1.6	5.5	21.4	0.32	1.71	2.31
Trifluralina 600	1.2	7.2	21.3	0.34	1.65	2.41
Trifluralina 1200	2.0	5.8	23.3	0.38	1.57	2.57
Trifluralina 2400	1.6	6.2	22.7	0.34	1.55	2.39
Control	1.4	7.4	26.7	0.37	1.42	2.46
F Treatments	1.89^{NS}	1.27^{NS}	1.69^{NS}	1.71^{NS}	1.41^{NS}	0.38^{NS}
C.V. (%)	21.13	23.2	13.1	12.2	16.5	12.1

NS – Not significant by Scott-Knott test ($p < 0.05$).

Doust et al. (2006) report that seed size is an important factor affecting the establishment of native species in forest recovery areas, where species with larger seeds have a higher establishment rate when compared to those with smaller seeds. It is noteworthy that the *H. stigonocarpa* seeds used in this experiment have a relatively high weight when compared to the other species (Table 1). Thus, it is deduced that there is more energy to feed their embryos. Supposedly because of this, the species was shown to be tolerant to all doses of the herbicides used, not showing differences in the early development when compared to the control.

Furthermore, seeds of the genus *Hymenea* present strong dormancy caused by tegument impermeability, especially attributed to the layer of palisade cells, which guarantees greater seed longevity, allowing seeds to germinate even after long periods of dispersion and under adverse conditions (Freitas et al., 2013). Therefore, it is possible to infer that all pre-emergent herbicides applied did not affect the viability of *H. stigonocarpa* seeds due to these characteristics of impermeable tegument and strong resistance, which conferred normal emergence for the species.

When evaluating the selectivity of glyphosate and sulfentrazone in *H. courbaril* seedlings, Gandini et al. (2014) confirmed that these herbicides have high potential to be used to control weeds in planting areas of this species at an early stage of development. The doses applied by the authors did not significantly affect the variables height, diameter, and root and shoot dry weight, showing no difference with the control. This corroborates the results of this research, where herbicides isoxaflutole, pendimethalin, and trifluralin also did not affect such parameters.

It should be noted that the selectivity of herbicides in native species is related to the absence of differences between treatments with and without the use of these products. Thus, it can be stated that all doses of the herbicides used in this research were selective for species *H. stigonocarpa*. Corroborating these results, Machado et al. (2013) comment that the absence of decreased seedling development in *Bowdichia virgilioides*, *Kielmeyera lathrophyton*, and *Plathymenia reticulata* are indications that these species are tolerant to glyphosate. According to Agostinetto et al. (2010), herbicide isoxaflutole was selective for eucalyptus genotypes because, regardless of the dose, it presented low phytotoxicity and there were no differences for the variables height, dry weight, and diameter when compared to the treatment without herbicide application.

Similar results were obtained when the herbicides were applied in the pre-emergence of *B. orellana*, since the number of leaves, seedling height, neck diameter, and root and shoot dry weight did not differ statistically from the control (Table 4).

Nonetheless, it is important to note that the herbicide treatments isoxaflutole at 200 g ai ha^{-1} and trifluralin at 600 and 1200 g ai ha^{-1} provided a mean number of emerged seedlings statistically higher ($p<0.05$) than that found in the control, indicating a possible stimulant effect for the products used since seeds were not scarified, as recommended by Campos Filho (2009). In general, the number of seedlings for these treatments was approximately four emerged seedlings, whereas in the control the average number was less than three emerged seedlings (Table 4).

Table 4 - Effect of herbicides and doses on the number of seedlings, number of leaves, height of seedlings (cm), stem diameter (mm) and root and shoot dry mass (g) of *B. orellana.*

Treatment	Number		Height	Diameter	Dry mass (g)	
	Seedlings	Leaves	(cm)	(mm)	Root	Shoot
Isoxaflutole 100	2.4 b	6.0	7.50	0.11	0.48	0.23
Isoxaflutole 200	4.0 a	5.8	7.28	0.11	0.43	0.20
Isoxaflutole 300	3.0 b	4.6	6.74	0.10	0.42	0.21
Pendimentalim 500	3.0 b	5.2	8.03	0.10	0.45	0.26
Pendimentalim 1000	3.0 b	5.9	7.17	0.11	0.41	0.24
Pendimentalim 4000	2.4 b	6.3	7.62	0.10	0.42	0.22
Trifluralina 600	3.6 a	6.0	7.87	0.10	0.42	0.22
Trifluralina 1200	3.4 a	6.0	7.71	0.12	0.41	0.22
Trifluralina 2400	2.4 b	5.8	7.50	0.11	0.43	0.25
Control	2.4 b	5.6	6.74	0.09	0.48	0.23
F Treatments	2.60*	1.16^{NS}	0.75^{NS}	0.98^{NS}	1.73^{NS}	1.60^{NS}
CV (%)	26.8	18.2	15.4	14.0	9.9	12.6

NS – not significant ($p > 0.05$) by F test; * significant ($p < 0.05$) by F test. Means followed by the same letter in the column do not differ by Scott-Knott test ($p > 0.05$).

Araújo Neto et al. (2018) commented that, given the low germination percentage of *B. orellana* seeds due to the dormancy imposed by impermeable tegument, treatments with stimulants to break dormancy are necessary for the production of seedlings of this species. It is assumed that herbicides isoxaflutole, at 200 g ai ha^{-1}, and trifluralin, at 600 and 1200 g ai ha^{-1}, may have broken seed dormancy, since the results found in this research show that these treatments were superior to the control, but the possible causes of the event are unknown.

When using herbicide setoxidim at doses of 184, 368, and 736 g ai ha^{-1} on *Guazuma ulmifolia* and *Senna multijuga*, Brancalion et al. (2009) also found effects similar to those of this study. The authors comment that herbicide setoxidim was even favorable to the growth of *S. multijuga* and *G. ulmifolia*, indicating a potential stimulant effect of setoxidim. Research by Pereira et al. (2015) demonstrated that different doses of the herbicide glyphosate did not cause toxicity in the native tree species *Cyntharexyllum myrianthum* and *Psidium cattleyanum*. The authors emphasize that some doses actually provided greater increases in several parameters evaluated when compared to the control, without herbicide application.

The results presented in Table 5 refer to the effects of herbicides isoxaflutole, pendimethalin, and trifluralin, applied at different doses in the pre-emergence of *A. hasslerii*. It should be noted that herbicide isoxaflutole, at 300 g ai ha^{-1}, was the only treatment that negatively affected all the variables evaluated for this species, since the mean values differ statistically ($P<0.05$) from the values obtained in the control. Moreover, no significant differences ($p > 0.05$) were observed in these variables for the other doses of isoxaflutole (100 and 200 g ai ha^{-1}), and for herbicides pendimethalin, at 500 g ai ha^{-1}, and trifluralin, at 600 g ai ha^{-1}, when compared to the control.

Table 5 - Effect of herbicides and doses on the number of seedlings, number of leaves, height of seedlings (cm), stem diameter (mm) and root and shoot dry mass (g) of *A. hasslerii.*

Tratamento	Number		Height	Diameter	Dry mass (g)	
	Seedlings	Leaves	(cm)	(mm)	Root	Shoot
Isoxaflutole 100	4.2 b	6.2 a	5.10 a	0.06 a	0.03 b	0.03 a
Isoxaflutole 200	4.0 b	6.1 a	4.63 a	0.07 a	0.03 b	0.03 a
Isoxaflutole 300	1.0 c	1.1 b	1.96 b	0.03 b	0.01 c	0.01 b
Pendimentalim 500	4.1 b	6.2 a	5.60 a	0.09 a	0.03 b	0.03 a
Pendimentalim 1000	4.6 b	6.3 a	5.68 a	0.08 a	0.06 a	0.04 a
Pendimentalim 4000	6.2 a	6.6 a	5.43 a	0.09 a	0.03 b	0.04 a
Trifluralina 600	4.4 b	6.4 a	5.88 a	0.08 a	0.03 b	0.05 a
Trifluralina 1200	5.2 a	7.3 a	5.43 a	0.08 a	0.03 b	0.04 a
Trifluralina 2400	6.2 a	6.0 a	5.22 a	0.07 a	0.03 b	0.03 a
Control	4.4 b	6.7 a	5.85 a	0.07 a	0.03 b	0.04 a
F Treatments	11.16**	16.9**	5.05**	7.57**	17.00**	8.34**
CV (%)	21.9	15.8	22.7	20.9	24.6	24.2

** significant ($p < 0.01$) by F test. Means followed by the same letter in the column do not differ by Scott-Knott test ($p > 0.05$).

Soto Gonzales et al. (2010) commented that, due to the low seed viability of *A. hasslerii*, the germination of this species can be influenced by several factors, including temperature changes, which can also affect dry weight. This low viability and resistance of seeds may be related to the highest dose of herbicide isoxaflutole leading to the lowest emergence rate of this species in this study. In the research by Brighenti & Muller (2014), the authors observed that herbicide isoxaflutole was the most phytotoxic herbicide for *Khaya ivorensis* and *Toona ciliata*, where all the variables evaluated presented a statistical difference to the control and the phytotoxicity levels were higher than those of other herbicides.

Silva et al. (2014) add that products applied in the pre-emergence of weeds, such as isoxaflutole, reach the soil directly and may cause greater damage by increasing the risk of exposure of soil phosphate-solubilizing microorganisms. The authors also noted that the application of isoxaflutole reduces root colonization of eucalyptus seedlings by arbuscular mycorrhizal fungi, also decreasing the potential for inorganic phosphate solubilization, directly affecting the early growth of the species. This fact corroborates the results obtained in this research, since the highest dose of the herbicide isoxaflutole directly affected the early development of *A. hasslerii* seedlings.

Polini et al. (2018) evaluated the selectivity of herbicides in native forest species of the Cerrado biome and concluded that herbicide imazapyr, when applied at low doses in post-emergence, is selective for tree species *Schinus terebinthifolia*, *Peltophorum dubium*, and *Handroanthus albus*; at high concentrations, however, it may affect their survival differently. Tavares et al. (2017) observed that the initial growth of *Caryocar brasiliense* plants was benefited from the application of 2,4-D subdoses for the variables leaf area, specific leaf area, and leaf area ratio. However, with increasing doses, there was a reduction in seedling growth, characterized by a decrease in leaf variables and in the total dry weight of plants. These results are similar to those found in this research, where herbicide isoxaflutole was selective at lower doses, but impaired the growth and development of *A. hasslerii* at the highest dose.

However, it is important to emphasize that the treatment with 1000 g ai ha^{-1} pendimethalin gave a statistically higher mean root dry weight ($p < 0.05$) compared to that found in the control. Moreover, pendimethalin at 4000 g ai ha^{-1} and trifluralin at 1200 and 2400 g ai ha^{-1} were statistically different ($p < 0.05$) for the number of emerged seedlings, with higher averages than those found in the control, indicating a possible stimulating effect of the products at these doses (Table 5).

When evaluating the use of forest species to reduce the clomazone residue in the environment, Cabral et al. (2017) found results similar to those of this study, in which the root dry weight of species *Jacaranda puberla*, *Inga marginata*, *Caesalpinia ferrea*, *Cedrela fissilis*, and *Schinopsis brasiliensis* showed an average increase of 29.6% with herbicide application. Fiore et al. (2016), studying seedlings of *J. puberla* and *Inga marginata*, found a significant average increase of root dry weight with herbicide application (25% increase when herbicide atrazine was applied, and 18% increase when herbicide 2,4-D was applied).

For herbicide trifluralin at doses of 600, 1200, and 2400 g ai ha^{-1} applied to *M. interrupta*, no statistical differences ($p > 0.05$) were observed for the number of seedlings, number of leaves, neck diameter, and root and shoot dry weight in relation to the control. However, the treatments with isoxaflutole and pendimethalin negatively influenced all variables evaluated, since the means were lower than the control, regardless of the dose used (Table 6).

Herbicide trifluralin, used at low concentrations, did not interfere with the initial growth of the pioneer species *Croton urucana* and *Muntingia calabura* (Moraes Neto et al., 2010). *Jatropha curcas* plants show high sensitivity to the herbicide isoxaflutole, since the doses of the product caused severe plant damage, negatively influencing all evaluated variables (Rocha et al., 2010; Inoue et al., 2014). These results are similar to those found in this research using species *M. interrupta*, where herbicide trifluralin did not affect the variables evaluated in relation to the control; herbicide isoxaflutole, in turn, damaged the seedlings of the species, regardless of the dose.

Table 6 - Effect of herbicides and doses on the number of seedlings, number of leaves, height of seedlings (cm), stem diameter (mm) and root and shoot dry mass (g) of *M. interrupta.*

Treatment	Number		Height\1	Diameter\1	Dry mass (g) \1	
	Seedlings\1	Leaves\1	(cm)	(mm)	Root	Shoot
Isoxaflutole 100	1.48 c	2.09 b	2.66 b	1.04 b	1.06 b	1.03 b
Isoxaflutole 200	1.08 d	1.25 c	1.60 c	1.02 b	1.05 b	1.01 c
Isoxaflutole 300	1.08 d	1.20 c	1.46 c	1.02 b	1.00 c	1.01 c
Pendimentalim 500	1.39 c	2.14 b	1.67 c	1.04 b	1.06 b	1.03 b
Pendimentalim 1000	1.08 d	1.29 c	1.44 c	1.02 b	1.03 c	1.01 c
Pendimentalim 4000	1.25 d	1.89 b	1.47 c	1.01 b	1.02 c	1.01 c
Trifluralina 600	2.18 a	2.52 a	3.25 a	1.09 a	1.09 a	1.06 a
Trifluralina 1200	1.22 a	2.35 a	3.18 b	1.10 a	1.10 a	1.05 a
Trifluralina 2400	1.26 a	2.23 a	3.16 b	1.10 a	1.12 a	1.06 a
Control	2.29 a	2.47 a	3.42 a	1.07 a	1.08 a	1.06 a
F Treatments	22.49**	10.04**	46.03**	8.31**	5.19**	7.89**
CV(%)	12.7	18.3	11.7	2.9	5.1	2.1

[1] Means transformed by square root x+1; ** significant ($p < 0.01$) by F test. Means followed by the same letter in the column do not differ by Scott-Knott test ($p > 0.05$).

It is highlighted that the herbicides acted differently, depending on the dose and mainly on the evaluated species. According to Duarte et al. (2006), the lower sensitivity of native species to herbicides may be related to the rate of absorption and metabolization of the active ingredient of the product; the higher this rate, the more harmful the herbicide action in the plant. Corroborating the results of this research, Monquero et al. (2011) state that the different concentrations of herbicides imazapyr, sulfentrazone, glyphosate, and metribuzin affected the survival of *Acacia polyphylla*, *Enterolobium contortisiliquum*, *Ceiba speciosa*, and *Luehea divaricata* differently.

The identification of Cerrado native plant species that can act as bioindicators of the action of herbicides, that is, that demonstrate sensitivity to herbicides, can assist in monitoring the impacts of the different products in the remaining areas of this biome (Batista et al., 2018). According to the results obtained in this research, it can be inferred that isoxaflutole, at the dose of 100 g ai ha^{-1}; pendimethalin, at 500 g ai ha^{-1}; and trifluralin, at 600 g ai ha^{-1}, if used with discretion and respecting the current legislation, present potential of use in vegetation recovery. Their use in intercropping with native species *H. stigonocarpa*, *B. orellana*, *A. hasslerii*, and *M. interrupta* represents an efficient alternative for the management of exotic grasses.

Conclusions

All herbicides and doses used did not affect the emergence and early development of seedlings of species *H. stigonocarpa* and *B. orellana*. For species *A. hasslerii*, only the dose of 300 g ai ha^{-1} of herbicide isoxaflutole was not selective. All doses of herbicide trifluralin showed selectivity for species *M. interrupta*.

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