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Article

Growth of Tree Species in Coexistence with Palisade Grass *Urochloa brizantha* (Hochst. ex A. Rich.) Stapf cv. Marandu

*Crescimento de Espécies Arbóreas em Convivência com Capim-Braquiarão **Urochloa brizantha** (Hochst. ex A. Rich.) Stapf cv. Marandu*

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ABSTRACT - The effect of palisade grass (*Urochloa brizantha*) was evaluated on the growth of five tree species from the Atlantic Forest biome in Seropédica, RJ, Brasil. This study consisted of five experiments in a completely randomized design. The effect of grass on the growth of *Cedrela fissilis*, *Guazuma ulmifolia*, *Schinus terebinthifolius*, *Sapindus saponaria*, and *Hymenaea courbaril* was tested in pots at each experiment. Height, collar diameter, and plant mortality were measured monthly. Shoot and root dry matter of tree species and grass were evaluated at 180 days. A strong interference of palisade grass was observed on the growth of the five studied species. The reduction of growth in height and collar diameter reached 32 and 29% in *S. saponaria* and 26 and 44% in *G. ulmifolia*, respectively. Grass interference was even higher on dry matter accumulation, promoting reductions in the shoot that ranged from 48% in *H. courbaril* to 90% in *G. ulmifolia* and *S. terebinthifolius*. Root dry matter of tree species was reduced between 28 and 84% in relation to the control without the presence of grass. The species *C. fissilis* had a mortality rate of 83% in coexistence with *U. brizantha*. The other species, except *S. saponaria*, presented mortality from 15 to 30% under competition. This study evidences the importance of controlling grasses in reforestation projects aiming higher gains in growth and survival of tree species.

Keywords: weed competition, *Cedrela fissilis, Guazuma ulmifolia, Schinus terebinthifolius, Sapindus saponaria, Hymenaea courbaril.*

*RESUMO - Avaliou-se neste trabalho o efeito da presença do capim-braquiarão (**Urochloa brizantha**) sobre o crescimento de cinco espécies arbóreas do bioma Mata Atlântica, em Seropédica-RJ. O estudo abrangeu cinco experimentos em delineamento inteiramente casualizado. Em cada experimento, testou-se em vasos o efeito da gramínea sobre o crescimento das espécies **Cedrela fissilis, Guazuma ulmifolia, Schinus terebinthifolius, Sapindus saponaria** e **Hymenaea courbaril**. Foram medidos mensalmente a altura, o diâmetro do coleto e a mortalidade das plantas. Aos 180 dias, avaliou-se também a massa seca de parte aérea e radicular das espécies arbóreas e da gramínea. Houve forte interferência do capim-braquiarão sobre o crescimento das cinco espécies estudadas. A redução de crescimento em altura e diâmetro do coleto chegou, respectivamente, a 32% e 29% em **S. saponaria** e a 26% e 44% em **G. ulmifolia**. A interferência da gramínea foi ainda maior sobre o acúmulo de massa seca, promovendo reduções na parte aérea que variaram de 48% em **H. courbaril** a 90% em **G. ulmifolia** e em **S. terebinthifolius**. A massa seca de raízes das espécies arbóreas reduziu entre 28% e 84% em relação*

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ao controle sem a presença da gramínea. ***C. fissilis*** *apresentou taxa de mortalidade de 83%, quando em convivência com* ***U. brizantha****. As demais espécies, à exceção de* ***S. saponaria****, também apresentaram mortalidade quando sob competição, variando de 15% a 30%. Este estudo evidencia a importância do controle de gramíneas em projetos de reflorestamento visando maiores ganhos em crescimento e sobrevivência das espécies arbóreas.*

Palavras-chave: matocompetição, *Cedrela fissilis, Guazuma ulmifolia, Schinus terebinthifolius, Sapindus saponaria, Hymenaea courbaril.*

INTRODUCTION

The reduction of native vegetation cover together with the history of soil use by intensive agriculture and/or livestock causes the formation of degraded areas, with reduced ecosystem and environmental services. One of the most used alternatives to recover previously forested areas with low expression of natural regeneration is the seedling planting of native tree species (Isernhagen et al., 2009).

The reforestation process seeks to promote conditions for the introduced native species population to be perpetuated in the site, remaining in the plant community indefinitely (Isernhagen et al., 2009). However, the successful establishment of these plants in the field depends both on favorable conditions intrinsic to the site and on adequate management in the first few years after planting.

Pastures occupy most of the areas destined to reforestation in Brazil, with a predominance of plants of the family Poaceae, such as species of the genera *Urochloa* P. Beauv. and *Megathyrsus* (Pilg.) BK Simon & SWL Jacobs, which compete with tree species for growth resources such as water, light, nutrients and space. Also, these plants may release allelopathic substances, interfering with growth, development (Rizzardi et al., 2001; Souza Filho et al., 2005), and survival of planted individuals (García-Orth and Martínez-Ramos, 2011; Pereira et al., 2013), composing the so-called weed competition process.

Competition caused by grasses is considered the main obstacle to the success of plantations for forest restoration (Brown et al., 2008). Thus, control of unwanted plants is essential during the early years of reforestation. However, it is not uncommon that the suppression of weed competition be neglected since there is a progressive increase in workforce costs necessary for cleaning and maintenance of planting areas (Toledo et al., 1996).

Several studies have investigated the interference of undesired plants on growth and yield of commercially important tree species of the genus *Pinus* and *Eucalyptus* (Silva et al., 2000; Toledo et al., 2001; Souza et al., 2003; Pereira et al., 2011; Carter et al., 2011; Bacha et al., 2016; Colmanetti et al., 2019). However, studies on competition between unwanted plants and native tree species are scarce. In one of the few studies, Maciel et al. (2011) found that the suppression of crowning in plants of Brazilian peppertree (*Schinus terebinthifolius* Raddi) and sacky sac bean (*Inga fagifolia* Willd. ex Benth.) up to 420 days after planting promoted reductions between 30 and 45% of height and stem diameter in relation to crowned plants.

Different tree species may also respond differently to the presence of exotic grasses. In an experiment using 15 L pots por 20 L plastic bags Monquero et al. (2015), showed that *Urochloa decumbens* significantly affected the height and diameter of *Enterolobium contortisiliquum* and *Luehea divaricata* after 110 days of coexistence. However, no significant effect was observed on the growth of *Ceiba speciosa*.

Studies to evaluate the sensitivity to weed competition of native species used in forest restoration projects are important, as they can provide information for selecting a set of species less sensitive to competition and, therefore, would generate a lower maintenance cost of planted areas. This information would allow prioritizing the weed competition control of the most sensitive species whose introduction in the area have a high functional or ecological value.

This study aimed to evaluate the effect of the presence of *Urochloa brizantha* (Hochst. ex A. Rich.) Stapf cv. Marandu on the survival and growth of five tree species of the Atlantic Forest biome in reforestation projects: *Cedrela fissilis* Vellozo (cedro-rosa), *Guazuma ulmifolia* Lamarck (bastardcedar), *Schinus terebinthifolius* Raddi (Brazilian peppertree), *Sapindus saponaria* L. (wingleaf soapberry), and *Hymenaea courbaril* L. (stinkingtoe).

MATERIAL AND METHODS

Characterization of the study site

The study was conducted in the field, in Seropédica, Rio de Janeiro State (22°45’18.48" S and 43°40’4.50" W). According to Köppen classification, the regional climate is type Aw (tropical with dry winters and rainy summers). The data from the Agricultural Ecology Automatic Weather Station between January 2011 and December 2016 indicated annual precipitation of 1,038 mm, with mean monthly temperatures varying from 19.24 to 28.66 °C, and a mean annual temperature of 23.84 °C (INMET, 2017).

Design and conduction of experiments

Five experiments were installed in April 2016 in a completely randomized design with a simple scheme. Each experiment was carried out using one of the following tree species used in reforestation for ecological purposes: *Cedrela fissilis* Vell., *Guazuma ulmifolia* Lam., *Schinus terebinthifolius* Raddi, *Sapindus saponaria* L., and *Hymenaea courbaril* L.. *G. ulmifolia* and *S. terebinthifolius* are species associated with early stages of succession, with fast growth in the field, *S. saponaria* has a moderate growth, while *C. fissilis* and *H courbaril* are classified as species of late successional stages, with slow development under field conditions.

Treatments consisted of the presence and absence of *Urochloa brizantha* (Hochst. ex A. Rich.) Stapf in coexistence with the tree species seedling. Each treatment had six replications, totaling 12 experimental units per experiment.

The experimental units consisted of pots with a capacity of 18 kg, with a height of 33.5 cm, a lower diameter of 22.50 cm, and an upper diameter of 27.4 cm. Each pot received a mixture of 8 kg of a Red-Yellow Argisol and 8 kg of a Haplic Planosol to obtain a medium-textured substrate, both collected at a depth of 20-40 cm, in soils adjacent to the experimental area.

Amounts of 50 g of single superphosphate and 10 g of micronutrient cocktail (FTE-BR12) were added into the soil volume of each pot, which is usually applied in the base fertilization (planting pit) in forest plantations with native species. These fertilizers were mixed to the substrate using a concrete mixer.

The experimental units were allocated in an open area and under direct sunlight. Each pot was placed on a concrete block in a 1 × 1 m spacing to avoid direct contact with the soil and facilitate the management operations of the experiment.

Each pot received a tree species seedling produced in a plastic tube with a volume of 280 cm^3, which was planted in the center of it. The grass *U. brizantha* was sown soon after seedling planting in six pots of each tree species. Thinning was carried out after seedling emergence, and four grass plants were maintained per pot, providing a density equivalent to 68 plants per m^2.

The pots were irrigated with 1.5 L of water at the end of the planting process. During the first two months after planting, the pots were irrigated three times a week, or at a lower intensity due to rainy periods, aiming at plant establishment. These pots were subjected to rainwater supply between 61 and 180 days after planting, being irrigated only during periods of prolonged drought. Thus, irrigation was carried out five times in July because no precipitation was registered in this period. Broadcast fertilizations were carried out in each pot at 60 and 120 days after planting with 10 g of urea and 6 g of potassium chloride (KCl).

The grass shoot was pruned at 6 cm in height at 90 days because it was close to the height of the seedlings of all species. This procedure was adopted to avoid competition for light. Weed plants that eventually germinated in pots of both treatments during the experimental period were manually removed.

Evaluations

Monitoring of shoot growth of each tree species was performed monthly by measuring the collar diameter and total height of each individual using a digital caliper graduated in millimeters and a stick graduated in centimeters, respectively.

Dead plant counting of each tree species was also carried out monthly, both in the presence and absence of *U. brizantha*.

The collection and separation of the shoot and root of the tree species and grass were carried out at 180 days after planting, time from which the pots could start limiting plant growth. The roots were washed in running water under a sieve to remove soil particles. Grass and tree roots were separated based on morphological aspects observed with the naked eye. Then, shoot (SDM) and root dry matter (RDM) of the tree species and grass were determined separately.

Data analysis

The data on species growth were evaluated for normality by the Shapiro-Wilk test and homoscedasticity by the Bartlett test, both at 5% probability level. Logarithmic transformations were performed to allow the data presenting a normal and/or homogeneous distribution of errors when these assumptions were not met. It occurred for the data of the variables shoot and root dry matter of the species *G. ulmifolia* and *S. saponaria*, as well as for the data of root dry matter of the species *S. terebinthifolius*.

Then, the data were submitted to analysis of variance by the F-test at 5% probability level. Due to the high mortality rate of the species *C. fissilis* in coexistence with *U. brizantha* at the end of 180 days of the experimental period, the analysis of variance for the variables height and collar diameter of this species were carried out with the data collected at 120 days after planting, before the death of individuals. Thus, the analysis of variance was not performed for the variables shoot and root dry matter of *C. fissilis*. All statistical analyses were carried out using the software R version 3.0.2 (R Development Core Team, 2010).

The relative reduction in the variables height, collar diameter, shoot dry matter, and root dry matter the tree species in coexistence with *U. brizantha* at six months after planting was calculated using the following equation:

Reduction (%) = 1 - (mean of the growth variable of the tree species in coexistence with *U. brizantha*/mean of the growth variable of the tree species in the absence of *U. brizantha*).

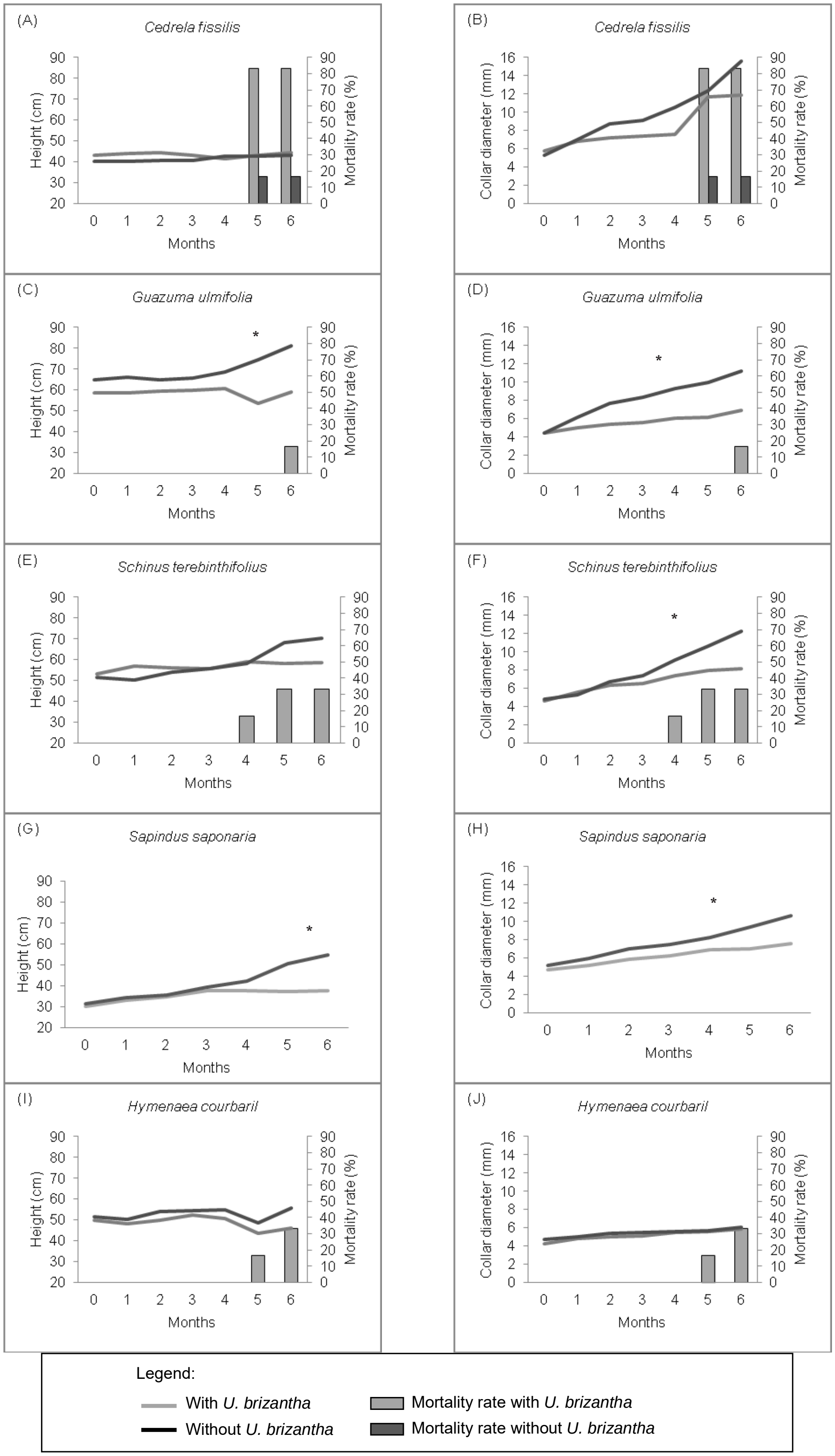
The monthly mortality rate of each tree species in both treatments was calculated by the number of dead individuals in relation to the number of planted individuals, being expressed as a percentage.

RESULTS AND DISCUSSION

Effect of *U. brizantha* on the survival rate of tree species

Tree species reacted differently to the presence of *U. brizantha* regarding the survival of seedlings planted until six months after planting. *C. fissilis* was the most sensitive species, with a mortality rate higher than 80% from the fifth month after planting (Figure 1), whereas only one plant of this species (16%) died during this period in the control treatment. Although in a lesser proportion, the presence of grass was also associated with mortality of plants of *G. ulmifolia* (16%), *S. terebinthifolius* (33%), and *H. courbaril* (33%), especially from the fourth month after planting. All individuals of these species survived in the absence of *U. brizantha*.

These results show that the presence of *U. brizantha* and the consequent competition due to it contributed to the mortality of tree species. This study was conducted under pot conditions with a high relative density of individuals of *U. brizantha* (68 plants m^{-2}) and restricted soil volume (approximately 18 L) when compared to field conditions, which may have provided an increased competition of the grass by water and nutrients in relation to what would occur in field conditions.



The plant mortality rate, when present, is shown in the y-axis. The asterisk indicates a significant difference between treatments at six months after planting by the F-test at 5% probability.

Figure 1 - Growth curves for height (A, C, E, G, and I) and collar diameter (B, D, F, H, and J) of plants of *C. fissilis*, *G. ulmifolia*, *S. terebinthifolius*, *S. saponaria*, and *H. courbaril* grown in coexistence or not with *U. brizantha*.

According to Medeiros et al. (2016), the lower investment in branches and leaves due to the stress imposed by the competition can compromise the survival of seedlings in the field or generate substantial yield losses by reducing the photosynthetic apparatus of plants. The proximity between the root system of tree species and that of *U. brizantha* may have promoted competition for water and nutrients, suggested by the redness of the edges of the leaf blade and, later, by the dryness of the apical bud and fall of leaves of part of plants growing in coexistence with *U. brizantha*.

Effect of *U. brizantha* on the growth and accumulation of biomass of tree species

The coexistence with *U. brizantha* promoted a lower growth of tree species until six months after planting. Except for *H. courbaril*, all species presented a lower growth rate of collar diameter, while all species showed a lower growth rate in height, except for *C. fissilis* (Figure 1).

A reduction in the mean height of some species, such as *C. fissilis*, *G. ulmifolia*, and *H. courbaril*, was observed in some months of the evaluated period (Figure 1). It occurred due to the dryness of the apical bud of some individuals and subsequent leaf fall, or, to a lesser extent, due to occasional branch breaks caused by wind or insect injuries.

Plants of *G. ulmifolia*, *S. saponaria*, and *S. terebinthifolius* presented significantly smaller collar diameter in the presence of *U. brizantha* at the end of 180 days of growth, while the height differed only for *G. ulmifolia* and *S. saponaria* (F-test; $p<0.05$) (Table 1). For the species *C. fissilis* and *H. courbaril*, height and mean collar diameter did not differ between treatments (Table 1). The lack of effect of the presence of *U. brizantha* on collar development in these two species possibly occurs because they have a late successional stage, i.e., slow-growing species.

Maciel et al. (2011) verified that *S. terebinthifolius* coexisted with an infestation of spreading liverseed grass (*Urochloa decumbens*) without interference in height and collar diameter up to 240 and 150 days after planting, respectively. In the present study, the height of *S. terebinthifolius* also did not present a significant difference when compared to the control at 180 days after planting (F-test; $p>0.05$). However, the presence of *U. brizantha* significantly reduced collar diameter, which suggests that its activities were concentrated in height growth in the presence of the undesired plant to the detriment of cambium activity.

According to Pitelli and Marchi (1991), eucalyptus plants under an intense infestation of unwanted plants tend to lose branches and leaves from the base of the canopy, thus showing small amounts of leaves at the apex, leading to etiolation. These authors reported that etiolation could be detrimental to the adult stage of plants even if unwanted plants are controlled. It occurs because the small leaf area located at the top of a long, thin stem does not promote substantial water flow to facilitate nutrient absorption. Also, the production of photosynthates is not enough to be translocated in quantity to promote vigorous root growth and provide energy to the processes of active absorption of soil nutrients.

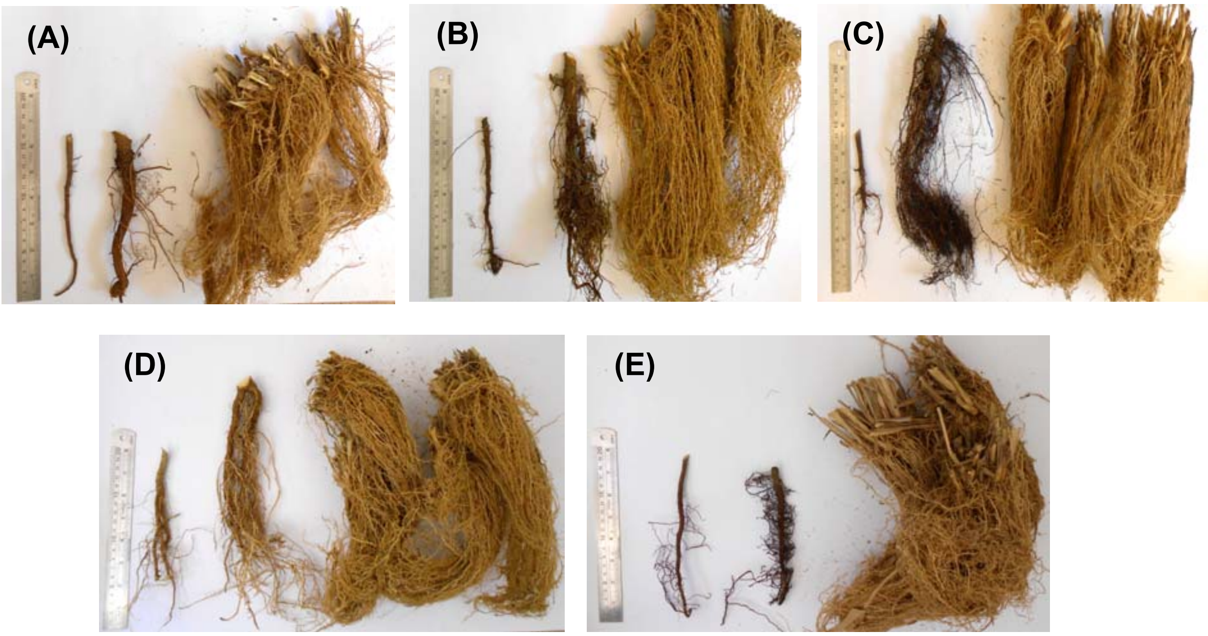
Table 1 **-** Height, collar diameter (CD), shoot dry matter (SDM), and root dry matter (RDM) of *C. fissilis*, *G. ulmifolia*, *S. terebinthifolius*, *S. saponaria*, and *H. courbaril* grown in coexistence or not with *U. brizantha* at 180 days after planting

Tree species	*U. brizantha*	Height (cm)	CD (mm)	SDM (g)	RDM (g)
C. fissilis	Present	41.2	7.5	6.8(1)	7.5(1)
	Absent	42.7	10.5	29.9(1)	12.4(1)
G. ulmifolia	Present	67.4	6.9	4.5	3.1
	Absent	91.5*	12.4*	44.1*	19.3*
S. terebinthifolius	Present	58.6	8.1	7.1	5.6
	Absent	70.4	12.2*	74.0*	18.2*
S. saponaria	Present	37.5	7.6	4.5	5.9
	Absent	54.9*	10.6*	36.1*	18.4*
H. courbaril	Present	45.9	5.9	4.2	3.7
	Absent	55.8	6.0	8.0*	5.1*

The asterisks within each species indicate that the treatments differ from each other by the F-test ($p<0.05$). (1) The F-test was not performed due to lack of replications in the treatment with *U. brizantha* (only one plant remained alive at the end of 180 days of growth).

Sensitivity of growth variables to weed competition imposed by *U. brizantha*

The percentage of reduction in height, collar diameter, shoot dry matter, and root dry matter of tree species grown in coexistence with *U. brizantha* at six months after planting is shown in Table 3. The values showed differences both in sensitivity of species to the competition imposed by the grass and in sensitivity of growth variables to show this degree of competitive interference. The results showed that the variables of dry matter measure (shoot and root) were more sensitive in detecting the effect of competition when compared to the variables height and collar diameter.



The center of the image shows the roots of an individual of the tree species in the absence of *U. brizantha*. On the right are the roots of *U. Brizantha*.

Figure 2 - The left side of each image shows the roots of an individual of the tree species in the presence of *U. Brizantha* at 180 days (*C. fissilis* (A), *G. ulmifolia* (B), *S. terebinthifolius* (C), *S. saponaria* (D), and *H. courbaril* (E)).

The coexistence with *U. brizantha* also promoted a reduction in dry matter production of all species. The most prominent effects were observed in the production of shoot dry matter of *S. terebinthifolius*, *G. ulmifolia*, and *S. saponaria* (Table 1). The statistical analysis was not carried out due to the high mortality rate of *C. fissilis*.

Similarly to the shoot dry matter, the root dry matter also had a significant reduction in response to the interference imposed by the grass species to a greater extent in the species *G. ulmifolia*, *S. terebinthifolius*, and *S. saponaria* (Table 1 and Figure 2).

Dry matter production by *U. brizantha*

Table 2 shows the shoot and roots dry matter of *U. brizantha* accumulated after 180 days of growth in coexistence with different tree species. Grass mass production was much higher when compared to that of tree species, resulting from the high competitive and growth capacity of this species.

Roots of *U. brizantha* presented a high dry matter in comparison to the tree species (Table 1), dominating the volume of substrate present in the pot and involving the roots of the tree species. Thus, Table 2 shows that shoot dry matter of *U. brizantha* varied from 11.3 to 20.9 times in relation to that of the tree species. On the other hand, the root dry matter of *U. brizantha* differed from 15.1 to 40.9 times in relation to that of the tree species. Thus, competition between species was reflected in a higher advantage of dry matter production of grass to limit the availability of growth resources and, consequently, tree species growth.

Table 2 **-** Shoot dry matter (SDM-B) and root dry matter (RDM-B) of *U. brizantha* in coexistence with *C. fissilis*, *G. ulmifolia*, *S. terebinthifolius*, *S. saponaria*, and *H. courbaril* at 180 days after planting; ratio between shoot dry matter of *U. brizantha* in relation to those of tree species (SDM-B/SDM) and ratio between root dry matter of *U. brizantha* in relation to those of tree species (RDM-B/RDM)

Species in coexistence	*U. brizantha*			
	SDM-B (g)	RDM-B (g)	SDM-B/SDM	RDM-B/RDM
C. fissilis	77.1	113.5	11.3	15.1
G. ulmifolia	84.2	124.7	18.6	40.9
S. terebinthifolius	91.7	121.3	12.9	21.7
S. saponaria	94.0	133.6	20.9	22.6
H. courbaril	85.3	140.4	20.5	38.0

Among the latter two, height was the least sensitive, showing a low capacity to express the effect of competition in comparison to plant mass production.

Previous studies have shown that the height of eucalyptus plants was also the characteristic with less sensitivity to the competition of weeds of the genus *Urochloa*. Dinardo et al. (2003) found that the coexistence of four plants of *Megathyrsus maximus* per m^2 with plants of *Eucalyptus grandis* generated losses of 61 and 45% for branch and leaf dry matter, respectively, at 180 days after transplanting to 50 L capacity asbestos boxes. In this study, height was the growth variable that showed the least impact (25.1%) when *M. maximus* was present.

Toledo et al. (2001) verified that the density of four plants of *U. decumbens* per m^2 in coexistence with *E. grandis* in a 50 L capacity asbestos container was sufficient to reduce stem, branch, and leaf dry matter, as well as leaf area and number of leaves by 55, 77, 55, 63, and 71%, respectively, in *E. grandis*. Reductions in the growth of eucalyptus plants increased as the density of *U. decumbens* increased (8 to 120 seedlings of *U. decumbens* per m^2). In this study, height and collar diameter were the least sensitive growth characteristics, with reductions of 18 and 28%, respectively (Table 3).

In this context, Colmanetti et al. (2019) evaluated the effect of different densities of *U. brizantha* cv. Marandu on the initial growth of *E. urograndis* in 20 L pots. The grass provided a reduction of 25.72% of total dry matter in the tree species from 22 plants m^{-2} at 90 days after planting when compared to the control, interfering negatively with eucalyptus growth. The effects were directly proportional to an increase in grass density, with a reduction of 63.9% of total dry matter of eucalyptus in coexistence with 111 plants of *U. brizantha* per m^2.

In the present study, the density of 68 plants of *U. brizantha* per m^2 per pot was well above the density of 22 plants of *U. brizantha* per m^2 adopted by Colmanetti et al. (2019). Under a lower density of competing plants, the effects of weed competition in this study are expected to be lower. However, reducing the density of *U. brizantha* would also reduce the intraspecific competition of this species, which could counterbalance the reduction of density.

Table 3 **-** Percentage of reduction in height, collar diameter (CD), shoot dry matter (SDM), and root dry matter (RDM) of tree species grown in coexistence with *U. brizantha* at six months after planting

Species	Height (cm)	CD (mm)	SDM (g)	RDM (g)
Cedrela fissilis	3%	28%	77%(1)	39%(1)
Guazuma ulmifolia	26%*	44%*	90%*	84%*
Schinus terebinthifolius	17%	34%*	90%*	69%*
Sapindus saponaria	32%*	29%*	88%*	68%*
Hymenaea courbaril	18%	3%	48%*	28%*

The asterisks indicate a significant difference in relation to the control (absence of *U. brizantha*) by the F-test ($p<0.05$). (1) The F-test was not performed due to lack of replications in the treatment with *U. brizantha* (only one plant remained alive at the end of 180 days of growth).

These results corroborate previous studies with exotic tree species, which evidenced the high degree of interference provided by grasses on growth. In this study, all tree species (*Cedrela fissilis* Vellozo, *Guazuma ulmifolia* Lamarck, *Schinus terebinthifolius* Raddi, *Sapindus saponaria* L., and *Hymenaea courbaril* L.) had a strong reduction in growth, and most of them presented increased mortality in coexistence with *U. brizantha*.

Similar studies should be conducted with other tree species of importance for reforestation programs to confirm this pattern or identify those more tolerant to weed competition. With these results, the choice of the most competitive tree species or tolerant to the coexistence with grasses with high competition capacity in reforestation areas, together with adequate control of these unwanted plants, especially at the initial stages, will lead to lower costs of replanting and weed control.

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