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Interference of *Urochloa decumbens* and *Panicum maximum* in the initial growth of six clones of *Eucalyptus urograndis*

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Abstract

Weeds play a strong pressure on the eucalyptus early growth, leading to a delay in their development. Therefore, many studies have tried to identify eucalyptus clones that are more tolerant to weed competition to supply information to producers, genetic improvement programs and the scientific community. The objective of this study was evaluate the interference of signal grass (*Urochloa decumbens*) and guinea grass (*Panicum maximum*) in the early growth of six clones of *Eucalyptus urograndis*, as well as the reciprocal effect. The experiment was conducted in an open and semi-controlled area in 8-L pots using a completely randomized experimental design with a 3 x 6 factorial scheme (*U. decumbens*, *P. maximum* and weed-free control and six eucalyptus clones). After ninety days of planting, the following variables were measured: eucalyptus stem diameter, height, total chlorophyll concentration, chlorophyll fluorescence (Fv/Fm), net assimilation rate and eucalyptus and weed dry biomass. In coexistence with Guinea grass (*Panicum maximum*), clone 3 (ms 709 H) exhibited a 78.2% reduction in dry biomass compared to clone 4 (C 219 H), which obtained the highest dry biomass. In coexistence with signal grass (*Urochloa decumbens*), clone 6 (ms 686 H) was the most negatively affected by weed competition, with an 80.7% lower dry biomass than clone 4. In general, clones 1 (ms 710 H), 2 (H 1069) and 4 were more resistant, and clones 3 and 6 were more sensitive to weed interference. Both weeds were affected by eucalyptus, but Guinea grass was more sensitive than signal grass.

Keywords: Competition; eucalyptus; Guinea grass; signal grass; weed management.
Abbreviations: DAP_Days after planting; BRADC_*Urochloa decumbens*; PANMA_*Panicum maximum*; Chl_Total chlorophyll concentration; *A*_Net assimilation rate; *E*_Transpiration rate; Diam_Stem diameter; Fv/Fm_Chlorophyll *a* fluorescence

Introduction

Eucalyptus is the most important forest crop in Brazil, accounting for 72% of planted forests and occupying more than 5.6 million hectares (Ibá, 2016). It is observed an annual yield increases in planted areas due to the success of genetic improvement programs and optimization of cultivation techniques, including weed control (Stape et al., 2004; Pereira et al., 2012).

The *Eucalyptus urophylla* × *Eucalyptus grandis* hybrid, *Eucalyptus urograndis* or simply "urograndis", combines disease and drought resistance and exhibits fast growth (Retief and Stanger, 2009), making it one of the most important species in Brazilian forestry. *E. urograndis* is the main material developed and planted in Brazil, and several commercial clones of this hybrid are available.

On the other side, the weed interference is one of the most important factors compromising forest productivity in eucalyptus plantations worldwide and has been studied over the past few decades (Sands and Nambiar, 1984; Ellis et al., 1985; Caldwell et al., 1995; Adams et al., 2003; Schaller et al., 2003; Coll et al., 2004; Garau et al., 2008; Cruz et al., 2010; Marques et al., 2015; Bacha et al., 2016). In addition to competing with crops for light, water and nutrients, the weed community also releases allelopathic compounds into the environment, which may interfere in eucalyptus growth (Pitelli, 1987; Brendolan et al., 2000; Toledo et al., 2001; Watt et al., 2003). Furthermore, weeds may indirectly interfere in crops by serving as intermediate hosts for pests and pathogens, sheltering venomous animals, making crop practices difficult and increasing fire risk (Pitelli, 1987; Pitelli and Marchi, 1991).

Species such as *Urochloa decumbens* (Stapf) R.D.Webster (syn. *Brachiaria decumbens* Stapf) and *Panicum maximum* (Jacq.) are commonly observed on eucalyptus plantations, since eucalyptus cultivation has been expanding into areas previously used for pasture. These weed species have some characteristics that make their control difficult, such as: fast growth, seed dormancy and regrowth, even after herbicide application, making crop establishment and management more difficult (Schreiner, 1988; Toledo et al., 2000, 2001; Cruz et al., 2010). In addition, competition with these weeds

may have detrimental effects on several physiological characteristics in eucalyptus, such as photosynthetic rate, stomatal conductance, transpiration rate and water use efficiency (Santos et al., 2015). The first year is the critical period of interference imposed by the weeds (Pitelli and Marchi, 1991; Nambiar and Sands, 1993; Florentine and Fox, 2003; Garau et al., 2009), which lead a reduced growth of up to 40% and 52% in stem diameter and height, respectively (Adams et al., 2003).

Since the clones have different response to weed interference during early growth (Cruz et al., 2010; Pereira et al., 2013; Graat et al., 2015), evaluate the performance of previously existing and promising clones of *E. urograndis*, during early growth, and with interference by *U. decumbens* and *P. maximum*, may provide information and support for genetic improvement programs. In this way, we aim to evaluate the interference of *U. decumbens* and *P. maximum* on the early development of six clones of *E. urograndis* (*E. urophylla x E. grandis*) as well as the reciprocal effect.

Results

BRADC and PANMA effects on eucalyptus

Significant interactions between factors were observed for: eucalyptus height, stem diameter, net assimilation rate, chlorophyll concentration and dry biomass, after 90 day of planted (Table 1). Significant differences in chlorophyll concentration (5.6% decrease), dry biomass (36.8% and 26.7% decreases with Guinea grass and signal grass, respectively) and height (6.83% decrease with signal grass) between the treatments with and without weed coexistence were observed for all clones. However, weed coexistence did not affect transpiration rates, Fv/Fm values, net assimilation rates or the stem diameters of eucalyptus plants.

In addition, significant differences between different eucalyptus clones were observed for stem diameter, plant height, chlorophyll concentration, photosynthesis rate and dry biomass, regardless of weed coexistence. There were no significant differences in Fv/Fm and transpiration rate (Table 1).

Eucalyptus height and stem diameter

No significant differences in plant height were observed between different clones without weed coexistence (control) (Table 2). With Guinea grass coexistence, clone 4 achieved a higher plant height than clones 3, 2 and 6 but was not significantly different from the plant heights of clones 1 and 5. With signal grass coexistence, clone 6 achieved a plant height 24.4% lower than clone 4, and the remaining clones achieved intermediate, but not significantly different, plant heights.

Without weed competition (control), stem diameters exhibited the same pattern observed for plant heights; clone 4 achieved a 46.7% larger stem diameter than clone 3, and the remaining clones achieved intermediate stem diameters (Table 3). With Guinea grass coexistence, clone 3 achieved a lower stem diameter than clones 1, 4 and 5. With signal grass coexistence, clone 3 again achieved a significantly lower stem diameter than clones 1, 2 and 4, and the stem diameter of clone 4 was significantly different from that of clone 6; clone 6 was not significantly different from any of the remaining clones. No significant differences were observed between weed coexistence treatments for each clone (Table 3).

Eucalyptus net assimilation rate and total chlorophyll concentration

No differences in net assimilation rates were observed between clones without weed competition or in the presence of signal grass (Table 4). With Guinea grass coexistence, clone 2 exhibited a significantly higher net assimilation rate than clone 1. The remaining clones exhibited intermediate net assimilation rates and were not significantly different from one another. No significant differences were observed between different coexistence treatments for each clone (Table 4).

For chlorophyll concentration, the same response pattern was observed for plants grown without competition (control) and with Guinea grass. Clone 4 exhibited a higher chlorophyll concentration than clones 3 and 6, whose chlorophyll concentrations were not significantly different from that of the remaining clones (Table 5). With signal grass, the chlorophyll concentration of clone 4 was higher than the concentrations in clones 3, 5 and 6. In addition, clone 2 was also better than clone 5, which had the lowest chlorophyll concentration.

Only clone 5 was sensitive to competition with signal grass; its chlorophyll concentration was 14.7% lower in the presence of signal grass than without weed coexistence (Table 5).

Eucalyptus dry biomass

The clones 3 and 6 with no coexistence had significantly lower dry biomass than the others clones (Table 6). Clone 1 exhibited the highest dry biomass, which was significantly different from clone 5 but not from clones 2 and 4. With Guinea grass coexistence, clones 3 and 6 were the most affected by weed interference, exhibiting the lowest dry biomass with decreases of 78.2% and 64.8%, respectively, relative to clone 4, which had the highest dry biomass. With signal grass coexistence, clones 1, 2 and 4 exhibited significantly higher dry biomass than clones 3, 5 and 6. Clone 6 had an 80.7% lower dry biomass than clone 4, which exhibited the highest.

Concerning the effects of weed coexistence on each clone, clone 1 had a significantly lower dry biomass in the presence of Guinea grass than without weed coexistence (45.4% decrease) or with signal grass (25.3% decrease) (Table 6). Clone 5 only had a significant decrease in dry biomass in coexistence with signal grass, which was 74.2% lower than the control. Clone 6 had a significantly lower dry biomass with either weed than weed-free, and there were no significant differences in dry biomass between the two weed coexistence treatments. Relative to the control, the dry biomass decrease was 42.6% and 63.1% for treatments with Guinea grass and signal grass, respectively (Table 6).

Eucalyptus interfering on BRADC and PANMA growth

Regarding the opposite effect, i.e., the interference of eucalyptus clones on weed growth, only clones 1 and 4 interfered on the signal grass growth at 90 DAP, resulting in dry biomass decreases of 58.7% and 57.4%, respectively, when compared to the control (Table 7). Only clones 1, 2 and 4 resulted in significant dry biomass decreases in Guinea grass (71.2%, 58.7% and 76.9%

Table 1. Effect of two weed species on six clones of eucalyptus after 90 days of coexistence.

Factor	Height (cm)	Diam (mm)	Fv/Fm	Chl (RU)	*A* (μmol CO_2 m^{-2} s^{-2})	*E* (mmol H_2O m^{-2} s^{-2})	Dry biomass (g)
COEXISTENCE							
CONTROL	39.5 A	5.4 A	0.780 A	41.0 A	10.9 A	40.1 A	37.4 A
PANMA	37.1 AB	4.9 A	0.761 A	38.7 B	13.2 A	36.9 A	23.6 B
BRADC	36.8 B	4.9 A	0.775 A	38.7 B	11.4 A	38.9 A	27.4 B
CLONE							
(1) ms 710 H	38.2 B	5.5 AB	0.782 A	39.8 BC	9.9 B	29.6 A	43.4 A
(2) H 1069	37.2 B	5.1 AB	0.780 A	41.7 AB	14.6 A	48.8 A	35.6 AB
(3) ms 709 H	33.6 C	3.9 C	0.764 A	36.0 D	12.3 AB	44.1 A	13.8 C
(4) C 219 H	42.4 A	5.8 A	0.780 A	44.2 A	11.4 AB	35.1 A	43.5 A
(5) ms 703 H	40.4 A	5.0 AB	0.754 A	38.7 BCD	12.9 AB	41.8 A	27.9 B
(6) ms 686 H	34.8 C	4.4 BC	0.770 A	36.7 CD	9.8 B	32.3 A	16.3 C
F	3.78**	3.5**	1.02^{ns}	4.85**	2.97**	1.79^{ns}	16.50**
P-value	<0.001	<0.001	0.4282	<0.0001	0.01	0.12	<0.0001

Means followed by the same letters within the same column were not significantly different according to Tukey's test at the 5% probability level. ^{ns} = non-significant difference at 5% level of probability on the F test. * = significant difference at 5% level ; ** = significant difference at 1% level. PANMA = *Panicum maximum*; BRADC = *Urochloa decumbens*; CONTROL = weed-free; Diam = stem diameter; Fv/Fm = chlorophyll *a* fluorescence; Chl = total chlorophyll concentration (relative units - RU); *A* = net assimilation rate; *E* = transpiration rate. Clone 1 = ms 710 H; Clone 2 = H 1069; Clone 3 = ms 709 H; Clone 4 = C 219 H; Clone 5 = ms 703 H; Clone 6 = ms 686 H.

Table 2. Interference of two weed species on height (cm) of six eucalyptus clones at 90 days after planting.

	CLONE							
Coexistence	(1)	(2)	(3)	(4)	(5)	(6)	F	P-value
CONTROL	40.9 A a	37.0 A a	35.7 A a	42.5 A a	42.1 A a	38.0 A a	1.45^{ns}	0.19
PANMA	36.6 A abc	35.3 A bc	31.4 A c	42.9 A a	41.4 A ab	34.8 A bc	4.87**	<0.001
BRADC	37.5 A ab	38.7 A ab	33.8 A ab	41.8 A a	37.5 A ab	31.6 A b	2.44*	0.0237
F	0.91^{ns}	0.80^{ns}	1.20^{ns}	0.41^{ns}	1.79^{ns}	1.90^{ns}	-----	-----
P-value	0.47	0.53	0.32	0.8	0.15	0.12	-----	-----

Means followed by the same uppercase letters within the same column, and lowercase letters within the same line, were not significantly different according to Tukey's test at the 5% probability level. ^{ns} = non-significant difference at 5% level of probability on the F test. * = significant difference at 5% level. ** = significant difference at 1% level. PANMA = *Panicum maximum*; BRADC = *Urochloa decumbens*; CONTROL = weed-free; Clone 1 = ms 710 H; Clone 2 = H 1069; Clone 3 = ms 709 H; Clone 4 = C 219 H; Clone 5 = ms 703 H; Clone 6 = ms 686 H.

Table 3. Interference of two weed species on stem diameter (mm) of six eucalyptus clones at 90 days after planting.

	CLONE							
Coexistence	(1)	(2)	(3)	(4)	(5)	(6)	F	P-value
CONTROL	54.7 A ab	50.3 A ab	39.4 A b	57.8 A a	51.8 A ab	48.6 A ab	2.22*	0.038
PANMA	54.9 A a	49.6 A ab	38.5 A b	57.2 A a	51.3 A a	44.2 A ab	3.37**	0.003
BRADC	55.4 A ab	52.8 A ab	37.9 A c	59.1 A a	46.3 A abc	40.3 A bc	3.61**	0.001
F	0.02^{ns}	0.32^{ns}	0.47^{ns}	0.06^{ns}	1.03^{ns}	0.93^{ns}	-----	-----
P-value	0.99	0.86	0.76	0.99	0.40	0.45	-----	-----

Means followed by the same uppercase letters within the same column, and lowercase letters within the same line, were not significantly different according to Tukey's test at the 5% probability level. ^{ns} = non-significant difference at 5% level of probability on the F test. * = significant difference at 5% level. ** = significant difference at 1% level. PANMA = *Panicum maximum*; BRADC = *Urochloa decumbens*; CONTROL = weed-free; Clone 1 = ms 710 H; Clone 2 = H 1069; Clone 3 = ms 709 H; Clone 4 = C 219 H; Clone 5 = ms 703 H; Clone 6 = ms 686 H.

Table 4. Interference of two weed species on net assimilation rate (μmol CO_2 m^{-2} s^{-2}) of six eucalyptus clones at 90 days after planting.

	CLONE							
Coexistence	(1)	(2)	(3)	(4)	(5)	(6)	F	P-value
CONTROL	8.7 A a	12.7 A a	8.7 A a	10.7 A a	14.5 A a	10.4 A a	2.89^{ns}	0.13
PANMA	8.5 A b	20.8 A a	14.6 A ab	10.9 A ab	13.6 A ab	10.4 A ab	4.97*	0.05
BRADC	12.7 A a	10.2 A a	13.7 A a	12.6 A a	10.5 A a	8.6 A a	2.12^{ns}	0.21
F	1.03^{ns}	6.18^{ns}	1.47^{ns}	0.25^{ns}	3.68^{ns}	0.90^{ns}	-----	-----
P-value	0.53	0.14	0.43	0.86	0.22	0.57	-----	-----

Means followed by the same uppercase letters within the same column, and lowercase letters within the same line, were not significantly different according to Tukey's test at the 5% probability level. ^{ns} = non-significant difference at 5% level of probability on the F test. * = significant difference at 5% level. PANMA = *Panicum maximum*; BRADC = *Urochloa decumbens*; CONTROL = weed-free; Clone 1 = ms 710 H; Clone 2 = H 1069; Clone 3 = ms 709 H; Clone 4 = C 219 H; Clone 5 = ms 703 H; Clone 6 = ms 686 H.

Table 5. Interference of two weed species on total chlorophyll concentration (relative units - RU) of six eucalyptus clones at 90 days after planting.

	CLONE							
Coexistence	(1)	(2)	(3)	(4)	(5)	(6)	F	P-value
CONTROL	41.1 A ab	42.5 A ab	36.6 A b	45.3 A a	42.1 A ab	38.1 A b	3.50**	0.002
PANMA	39.5 A ab	40.8 A ab	35.6 A b	43.6 A a	38.2 AB ab	35.4 A b	3.90**	0.001
BRADC	38.8 A abc	41.4 A ab	36.0 A bc	43.5 A a	35.9 B c	36.7 A bc	3.91**	0.001
F	0.79^{ns}	0.61^{ns}	0.17^{ns}	0.20^{ns}	3.73**	0.63^{ns}	-----	-----
P-value	0.54	0.66	0.95	0.94	0.009	0.64	-----	-----

Means followed by the same uppercase letters within the same column, and lowercase letters within the same line, were not significantly different according to Tukey's test at the 5% probability level. ^{ns} = non-significant difference at 5% level of probability on the F test. ** = significant difference at 1% level. PANMA = *Panicum maximum*; BRADC = *Urochloa decumbens*; CONTROL = weed-free; Clone 1 = ms 710 H; Clone 2 = H 1069; Clone 3 = ms 709 H; Clone 4 = C 219 H; Clone 5 = ms 703 H; Clone 6 = ms 686 H.

Table 6. Interference of two weed species on dry biomass (g) of six eucalyptus clones at 90 days after planting.

	CLONE							
Coexistence	(1)	(2)	(3)	(4)	(5)	(6)	F	P-value
CONTROL	54.8 A a	42.5 A ab	19.5 A c	45.9 A ab	37.6 A b	23.9 A c	17.5**	<0.0001
PANMA	29.9 C ab	26.6 A ab	8.5 A b	39.0 A a	28.7 A ab	13.7 B b	6.67**	0.01
BRADC	40.9 B a	34.3 A a	13.3 A b	45.6 A a	9.7 B b	8.8 B b	31.0**	<0.0001
F	46.8**	6.54^{ns}	3.27^{ns}	1.19^{ns}	4.91*	14.2*	-----	-----
P-value	0.005	0.14	0.14	0.43	0.02	0.02	-----	-----

Means followed by the same uppercase letters within the same column, and lowercase letters within the same line, were not significantly different according to Tukey's test at the 5% probability level. ^{ns} = non-significant difference at 5% level of probability on the F test. * = significant difference at 5% level. ** = significant difference at 1% level. PANMA = *Panicum maximum*; BRADC = *Urochloa decumbens*; CONTROL = weed-free; Clone 1 = ms 710 H; Clone 2 = H 1069; Clone 3 = ms 709 H; Clone 4 = C 219 H; Clone 5 = ms 703 H; Clone 6 = ms 686 H.

Table 7. Effect of coexistence with six eucalyptus clones on dry biomass (g) of two weed species.

Treatment	PANMA	BRADC
CONTROL	33.0 A	40.7 A
(3) ms 709H	28.3 A	34.3 AB
(6) ms 686H	27.6 A	26.3 AB
(5) ms703H	23.1 AB	22.9 AB
(2) H1069	13.6 BC	23.6 AB
(1) ms 710H	9.5 C	16.8 B
(4) C219H	7.6 C	17.3 B
F	12.1**	4.94**
P-value	0.0001	0.009

Means followed by the same letter within the same column were not significantly different according to Tukey's test at the 5% probability level. ** = significant difference at 1% level of probability on the F test. PANMA = *Panicum maximum*; BRADC = *Urochloa decumbens*; CONTROL = weed-free; Clone 1 = ms 710 H; Clone 2 = H 1069; Clone 3 = ms 709 H; Clone 4 = C 219 H; Clone 5 = ms 703 H; Clone 6 = ms 686 H.

when compared to the control, respectively). Overall, both signal grass and Guinea grass exhibited lower dry biomass when grown with clones 1 and 4.

Discussion

The weed interference observed in the present study, which had negative effects on some eucalyptus variables, such as: plant height, stem diameter, dry biomass, chlorophyll concentration and net assimilation rate (Tables 1 to 6), is in accordance with several previous studies that reported a higher sensitivity of eucalyptus plants to interference during the first year following their establishment (Adams et al., 2003; Florentine and Fox, 2003; Garau et al., 2009; Tarouco et al., 2009). Interference by weed community composed mainly of signal grass was observed to have a negative effect on *Eucalyptus urophylla* between 14 and 140 days, which was characterized as a critical period for weed interference (CPWI) (Toledo et al., 2000).

Weed density is also an important factor on weed interference in the early growth stages of several eucalyptus species. Reduced growth was observed for *E. grandis* from a density of 4 *P. maximum* plants m^{-2} (Dinardo et al., 2003). Similar results were reported for interference of *U. decumbens* on *E. grandis* (Toledo et al., 2001). Bacha et al. (2016) observed that regrowth of signal grass at a density of 2.6 plants m^{-2} caused reduced growth in leaf area and dry biomass of *E. urograndis* up to 89% and 87%, respectively.

Differences in responses between different clones were observed for all variables measured. The degree of weed interference on crops may be determined by several factors, such as: the weed species, density and distribution, edaphoclimatic characteristics of the region and the species/clone/cultivar used (Bleasdale, 1960; Pitelli, 1985). Thus, it is possible to observe that some clones were high sensitivity to interference imposed by weeds (clones 3 and 6), but also some of them were more tolerant, such as clones 1 and 4. Silva et al. (1997) observed that *Corymbia citriodora* (ex *E. citriodora*) was more sensitive to competition with *Brachiaria brizantha* than *E. grandis.* Different responses for different *E. urograndis* clones have also been reported (Cruz et al., 2010; Graat et al., 2015).

The present results indicate that clones 3 and 6, which were the most affected by weed interference, and clones 1 and 4, which grew better, exhibited different behaviors regarding resource uptake from the environment. During the first months after planting, eucalyptus plants allocate large amounts of nutrients and photoassimilates to the roots to meet their water and nutrient demands (Gonçalves et al., 2000). However, weed competition may have decreased resource availability. It is therefore likely that clones 3 and 6 were not able to maintain their normal metabolic levels, resulting in more pronounced decreases in the variables measured.

Furthermore, the high competitive capacity of grasses, which affects eucalyptus height, stem diameter and dry biomass, is due to their fast root growth. Their fast root growth enables them to better exploit environment resources and makes them very aggressive, especially during regrowth (Bacha et al., 2016), which enables rapid colonization of an area (Toledo et al., 1996).

Nitrogen is a key nutrient for chlorophyll formation, and nitrogen concentration is directly reflected in leaf chlorophyll concentration (Donahue et al., 1990). Therefore, the observed chlorophyll concentrations may be directly related to the fertilizations performed at 20 and 55 DAP. Because clones 3 and 6 probably had a lower competitive capacity (for nutrient uptake), they exhibited lower chlorophyll concentrations than clone 4 (which grew more). In addition, several studies have highlighted that the amount of chlorophylls is directly related to the photosynthetic rate and consequently, plant growth and dry biomass production (Porra et al., 1989; Chappelle and Kim, 1992; Ripullone et al., 2003). Therefore, the present results (Tables 1 to 6) indicate that clones 3 and 6 suffered more from weed competition, whereas clones 1 and 4 were more tolerant of weed coexistence.

In terms of the interference of eucalyptus clones on weed growth, the most resistant clones were also those that most affected weed growth. In addition, Guinea grass was more sensitive than signal grass to coexistence with eucalyptus (Table 7). It was also observed that there was interaction between eucalyptus clones and weed plants, as reported in previous studies (Cruz et al., 2010; Pereira et al., 2013), in which the rate of growth and the architecture of eucalyptus plants were different among the clones. Thus, it is possible to infer that the different heights observed in the clones, such as 31.4 cm for clone 3 and 42.9 cm for clone 4, may have influenced the growth behavior of signal grass and Guinea grass.

Materials and Methods

Experimental area

An experiment was conducted in 8-L pots in an open and semi-controlled area in the municipality of Jaboticabal, São Paulo, Brazil (595 m altitude; 21°15'22" S; 48°18'58" W) until 90 days after eucalyptus planting (DAP). The region's climate is classified as Cwa according to the Köppen (1948) climate classification; it is subtropical and relatively dry in winter and has rainy summers, with average annual rain fall of 1225 mm and an average temperature 22 °C. Each pot was considered an experimental plot and watered daily to field capacity.

Plant materials

Seedlings of the following eucalyptus hybrid (*E. urophylla x E. grandis*) clones were used: ms 710 H (clone 1), H 1069 (clone 2), ms 709 H (clone 3), C 219 H (clone 4), ms 703 H (clone 5) and ms 686 H (clone 6). The seedlings were approximately 90 days old when they were planted with average heights of 20 cm, 10 to 12 leaves, 1.25-mm stem diameters and active root systems. Bifurcated seedlings were avoided.

The substrate consisted of a 2:1 soil: sand mix (v:v). The soil was collected from the surface layer of a Dark Red Latosol. After substrate preparation and planting of the seedlings, nitrogen fertilizer consisting of 50 mL of 1% urea (equivalent to 130 kg ha^{-1}) was applied at 20 DAP, and nitrogen fertilizer consisting of 50 mL of 2% urea (260 kg ha^{-1}) was applied at 55 DAP. A topdressing with 4-14-8 (NPK) fertilizer equivalent to 400 kg ha^{-1} was also performed at 60 DAP.

Guinea grass (*P. maximum*; PANMA) and signal grass (*U. decumbens*; BRADC) seedlings were obtained by sowing diaspores in styrofoam cell trays containing substrate for vegetables to standardize weed size at transplantation. Weed seedlings were transplanted into pots when they presented two tillers. One weed seedling was transplanted into each pot 5 cm away from the eucalyptus seedling on the day of eucalyptus planting.

Treatments and experimental design

A completely randomized experimental design was used with a 3 x 6 factorial scheme; the factors were the presence of guinea grass, signal grass or weed-free control and six eucalyptus clones (1, 2, 3, 4, 5 and 6), for a total of 18 treatments. Three replicates were carried out per treatment.

Assessed variables

At 90 DAP, the following variables of the eucalyptus plants were measured: plant height (measured from the base of the plant to the top with a 100-cm wooden ruler), stem diameter (measured 2 cm from ground level using a digital caliper) and net assimilation rate and transpiration (on the third fully expanded leaf using an LI-6400 infra-red gas analyzer (LiCor)). For the gas exchange measurements, the following settings were used: reference CO_2 of 350 μmol mol^{-1}, reference H_2O of 9 mmol mol^{-1}, air temperature of 25 °C in the chamber, atmospheric pressure of 1000 KPa, flow rate of 400 μmol s^{-1} and photosynthetically active photon flux (quantum) of 1000 μmol m^{-2} s^{-1}. The total chlorophyll concentration (SPAD-502, Minolta) and chlorophyll *a* fluorescence (Fv/Fm; PEA, Hansatech) were also determined on the third fully expanded leaf. Following the measurements, eucalyptus and weed plants were cut at ground level and placed in a forced air oven at 70°C for 96 hours for dry biomass determination.

Statistical analysis

The data were subjected to analysis of variance (ANOVA) using the F-test followed by Tukey's test at a 5% probability level. The variables were transformed to meet the assumptions of normality and homoscedasticity. All statistical analyses were performed by using SAS (Statistical Analysis System) 9.3.

Conclusion

It may therefore be concluded that clones 1 (ms 710 H), 2 (H 1069) and 4 (C 219 H) were more resistant to weed interference, whereas clones 3 (ms 709 H) and 6 (ms 686 H) were more sensitive. Only clones 1 and 4 affected the growth of signal grass, and clones 1, 2 and 4 affected the growth of Guinea grass. Therefore, Guinea grass was more sensitive to coexistence with eucalyptus plants.

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