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Weed control strip influences the initial growth of *Eucalyptus grandis*

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ABSTRACT. Reforestation in Brazil is conventionally carried out with a 50-cm weed control strip, using mechanical or manual hoeing or herbicides. The aim of this study was to determine effects of varying the width of the herbicide-treated strip on the establishment of *Eucalyptus grandis*. Eucalyptus plants were transplanted in Araraquara and Altinópolis counties, São Paulo State, Brazil. In Araraquara, the following treatments were evaluated: 0, 25, 50, 75, 100 and 150-cm wide strips, treated with herbicide, on either side of the eucalyptus row; in Altinópolis, the width of the strip on either side of the eucalyptus row was 0, 25, 50, 75, 100, 125 or 150 cm. Were evaluated dry matter of leaves, branches and stem and leaf area at 270 days after planting (270 DAP), chlorophyll content (400 DAP), stem diameter and eucalyptus plants height (410 DAP). In Araraquara, the main weed was *Panicum maximum*, and in Altinópolis, it was *Rhynchelytrum repens*. For both areas, a minimum of 75 cm of treated strip was required to minimise weed interference with eucalyptus plants' development.

Keywords: reforestation, weed interference, weed competition.

Faixa de controle de plantas daninhas influencia o crescimento inicial de *Eucalyptus grandis*

RESUMO. O reflorestamento no Brasil é normalmente realizado com uma faixa de controle de plantas daninhas de 50 cm, utilizando capina mecânica ou manual ou herbicidas. O objetivo deste estudo foi avaliar os efeitos da variação da largura da faixa tratadas com herbicidas sobre o estabelecimento de *Eucalyptus grandis*. Plantas de eucalipto foram transplantadas nos municípios Araraquara e Altinópolis, Estado de São Paulo, Brasil. Em Araraquara, os seguintes tratamentos foram avaliados: 0, 25, 50, 75, 100 e 150 cm de larguras de faixas, tratadas com herbicidas, em ambos os lados da linha de eucalipto; em Altinópolis, a largura da faixa em ambos os lados da linha de eucalipto foi de 0, 25, 50, 75, 100, 125 ou 150 cm. Foram avaliados a matéria seca de folhas, ramos e caule e área foliar aos 270 dias após o plantios (DAP), teor de clorofila (400 DAP) e altura e diâmentro do caule (410 DAP). Em Araraquara, a principal espécie foi *Panicum maximum*, em Altinópolis, foi *Rhynchelytrum repens*. Para ambas as áreas, foi necessário o mínimo de 75 cm de largura de faixa tratada para minimizar a interferência das plantas daninhas no desenvolvimento das plantas de eucalipto.

Palavras-chave: reflorestamento, interferência de plantas daninhas, competição com planta daninhas.

Introduction

The presence of weeds can be detrimental to the establishment and maintenance of eucalyptus forests. Weeds compete with eucalyptus for water, nutrients, light and other factors, reducing qualitative and quantitative characteristics of the eucalyptus (SOUZA et al., 2010). This competition occurs when the supply of one or more factors essential to growth and development falls below the combined demands of the plants (ANDERSON, 1996). Weed interference with forest species can be divided into three groups: (i) direct (e.g., competition and allelopathy); (ii) indirect (host of pests and diseases); and (iii) interfering with productive activities (e.g., manuring, irrigations, harvest) (SOUZA et al., 2003).

Eucalyptus forest systems benefit from the presence of weeds through increased biotic diversity on the first trophic level and through increased protection of soil against erosion and nutrient loss. McNabb et al. (1995) propose that within a plantation, plants are not inherently undesirable; they only become unwanted when they prevent the plantation management from reaching its desired target.

Toledo et al. (2001) observed that *Urochloa decumbens* (syn. *Brachiaria decumbens*), at a density of at least 4 plants m^{-2}, has reduced the initial growth of *Eucalyptus* plants. This weed reduced stem diameter by 27.8%; plant height by 18.5%; leaf number by 70.6%; leaf area by 63.3%; and stem, branch, and leaf dry weights by 55.2, 77.3 and 55.3%, respectively, on average. Eucalyptus height was not a good parameter to use for evaluation of the interference of *U. decumbens*.

Kogan (1992) and Garau et al. (2009) stated that weeds are most competitive during the first two years after planting of eucalyptus trees. Weed community composition is another important factor that can influence eucalyptus growth. The degree of competitiveness of a weed will depend on its efficiency in using local resources. Cruz et al. (2010) and Toledo et al. (2000a) observed that aggressive annual species such as *Panicum maximum* and *U. decumbens* are more competitive at the first stage of *Eucalyptus* sp. growth, and shrub and arboreos species are more competitive at the advanced stage of growth. Studies by Toledo et al. (2000a, 2003) demonstrated that the width of control strips reflected in the growth of eucalyptus trees, but this effect depends on several factors such as the composition of the weed community, eucalyptus species and weather.

Vegetation management during the establishment of commercial plantations is a major factor that contributes to improvement of the final yield (TOLEDO et al., 2003; APARICIO et al., 2010). Development of a sound vegetation management strategy requires a definite and sequential plan of action. A good understanding of the basic criteria involved in weed-tree interactions, growth-limiting factors, the minimum tolerable weed thresholds and an understanding of the best parameters of measurement are needed to delineate an appropriate management approach (GARAU et al., 2009).

The aim of this study was to find the effects of the width of herbicide-treated strips on the establishment of a *Eucalyptus grandis* forest.

Material and methods

The study was carried out in two locations: Araraquara and Altinópolis counties, São Paulo State, Brazil. After the eucalyptus trees were planted, glyphosate (1.08 kg a.e. ha^{-1}) was applied to the entire area. The treatments consisted of different widths of strips without weeds. To keep the strips weed-free, 0.72 kg a.i. ha^{-1} of oxyfluorfen was applied.

The experiments were designed as a randomised complete block with four replicates in Araraquara and five replicates in Altinópolis. Eucalyptus plants (*Eucalyptus grandis* W. Hill ex. Maiden) were planted in a 3 x 3 m distance. In the first experiment, each block had four rows of plants with six eucalyptus trees per row and eight measurable plants per treatment. The second experiment had five rows of plants in each block, with six eucalyptus trees per row and twelve measurable plants per treatment. The experiment in Araraquara had the following weed-free treatments: 0-, 25-, 50-, 75-, 100- and 150-cm strips on either side of the eucalyptus row. In Altinópolis, weed-free areas were strips of 0, 25, 50, 75, 100, 125 and 150 cm on either side of the eucalyptus row. The data were subjected to the F-test for analysis of variance, and the means were compared with Tukey's test.

Weed species from all treatments were collected, identified, counted, and dried. Based on the numbers of weed plants per square meter and the biomass per square meter, relative density, dominance, frequency and importance were calculated for each population following Mueller-Dombois and Ellemberg (1974). At the Araraquara experiment weeds were sampled at 60, 90 and 120 days after planting (DAP) and in Altinópolis they were sampled at 90, 120, 150 and 180 DAP. To collect the weeds, four subsamples were taken using 0.25 m^2 quadrates for each treatment.

At 270 DAP, one representative eucalyptus plant per treatment was collected, which included the leaves, branches and stem dry matter as well as the leaf area of these plants (LI-COR, Model LI3000A). At 400 DAP, the total chlorophyll concentration was determined (Minolta, Model SPAD502). Eucalyptus plant measurements included stem diameter and height, measured until 410 DAP.

Results and discussion

Vegetation richness

Araraquara - A total of 20 species were observed to be the most common weeds present in the area during the study. Dicotyledonous species covered 75% of the total area. Weeds that showed the most relative importance (RI) were *Panicum maximum* Jacq., *Commelina benghalensis* L. and *Sida glaviozi* K. Shum.

Altinópolis - The weed community was composed predominantly of 17 species, of which dicotyledonous species comprised 77% of the total area. The species with the greatest RI were *Rhynchelyntrun repens* (Willd.) C.E. Hubb., *Urochloa decumbens* (Stapf) R. D. Webster (syn. *Brachiaria decumbens* Stapf.), *Spermacoce latifola* Aubl., *Glycine wightii* (R.Grah. ex Wight & Arrn.) Verdc. and *Portulaca oleracea* L.

In both locations, dicotyledonous species were more prevalent, although a few monocotyledonous species showed higher RI levels. Buttonweed (*S. latifolia*), a common weed species in the eucalyptusgrowing areas in Brazil, interfered with the growth of the plants. Plant height, stem diameter, dry weights and leaf area showed that the "before weed interference period" (BIP), the "whole period of prevention of interference" (WPPI) and the "critical period for prevention of interference" (CPPI) were 40, 60, and 60 DAP, respectively, under winter conditions; under summer conditions, the BIP, WPPI and CPPI were 20, 80 and 20 to 80 DAP (COSTA et al., 2002). For *Commelina benghalensis,* another common weed species, the BIP, WPPI and CPPI were 20, 60, and 20 to 60 DAP, respectively, in winter conditions. In summer conditions, WPPI was shorter than BIP (10 and 40 DAP, respectively); therefore it was not possible to determine CPPI in these conditions (COSTA et al., 2004). Toledo et al. (2000b) observed that young *Eucalyptus grandis x E. urophylla* clones were very susceptible to weed interference by *U. decumbens* and *S. latifola*, and to assure normal tree development, it was necessary to maintain a weed-free period (WPPI) of 140 DAP.

Pitelli (1987) found that gramineous species, such as *Panicum maximun,* can, depending on site resources, modify their growth pattern to produce more shoots, making them more competitive. Dinardo et al. (2003) verified that at 110 and 190 days after transplanting, *P. maximum* in densities higher than 4 plants m^{-2} reduced stem diameter (30.8 and 46.5%); plant height (25.1 and 22.5%); stem (40.2 and 31.3%), branch (61.3 and 54.1%), root (53.7 and 51.8%) and leaf (44.6 and 38.5%) dry mass; branch (22.5 and 23.2%) and leaf (20.7 and 20%) numbers; and foliar area (34 and 17.1%) of eucalyptus plants. Little (1996) explained that selective weed control is not an option in eucalyptus plantations unless there is a mono-specific stand of competing vegetation present, as any remaining weed community will still cause significant growth reduction. We observed that the most vigorous weed growth occurred during the first and second years after eucalyptus tree planting.

The aggressive characteristics of weeds, such as large number of seeds, seed dormancy, discontinuous germination, effective dispersal mechanisms and population heterogeneity, are even very important during crop establishment. During this phase, weeds may rapidly capture resources and occupy space; this is often linked to their competitive ability because rapid growth requires the prompt and efficient conversion of resources into biomass. The control treatment was dominated by competitive perennial species such as *Panicum maximum* in Araraquara. Annual grasses, such as *Urochloa decumbens*, and perennial species, such as *Glycine wightii*, were damaging weeds in Altinópolis due to their growth habits. The major changes in species composition over time were a decrease in frequency and abundance of some annual weeds in all treatments as well as the increase in frequency and importance of perennial species and those characteristics of more stable vegetation communities. These results agree with works reported by Marshall and Nowakowski (1992) and by Willoughby and McDonald (1999), who observed that in the United Kingdom, perennials effectively outcompeted annual species by occupying any exposed soil for annual weed germination.

Plant height and diameter

Araraquara – Analysis indicated a linear relationship between plant height and diameter over different sizes of weed-free strip (Figure 1). The untreated plots and the plots with 25-cm width strips showed the lowest heights, 3.42 and 3.58 m, respectively. The 50, 75 and 100-cm strip treatments showed intermediary values, and the weed-free treatment showed a higher plant height of 4.40 m. The 150-cm treatment also showed the highest stem diameter, 5.84 cm. The untreated strip as well as the 25 and 50-cm width strip treatments showed the lowest diameters: 4.22, 4.49, and 4.76 cm, respectively.

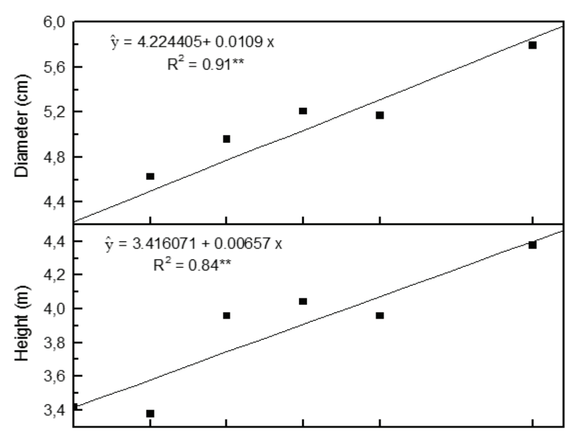

Figure 1 Response of eucalyptus plant diameter and height to weed herbicide-treated strip width. Araraquara County, São Paulo State, Brazil.

A reduction in the availability of moisture and nutrients leads to reduced tree growth and survival (DAVIES, 1987). In our studies, trees in the control plots suffered the most from weed competition, exhibiting comparatively poor growth and stem-diameter reduction. Interestingly, the heights of the trees in the control plot were not significantly reduced. Perhaps light competition stimulated plants to grow taller in search of the necessary solar radiation.

Altinópolis – Results from the Altinópolis trial, which included an additional width strip (125 cm), were very similar to those from Araraquara (Figure 2).

In South Africa, eucalyptus crown growth of 10 cm can be attained in 41 days with 20% weeding or in 66 days with 0% weeding (SCHUMANN et al., 1994). Little et al. (1994) used the tree crown diameter as an indication of tree performance. They observed a distinct exponential increase in median crown diameter with weed-free strip width and concluded that a 2-m strip width with no weeding at all in the 1 m between rows proved to be the best management strategy. Light competition can increase plant height at the expense of stem diameter, making eucalyptus more susceptible to tumble (NAVAS, 1991). Eucalyptus trees are extremely susceptible to interspecific competition from establishment until canopy closure, after which the light-limiting effect of canopy closure excludes the development of a competitive weed load.

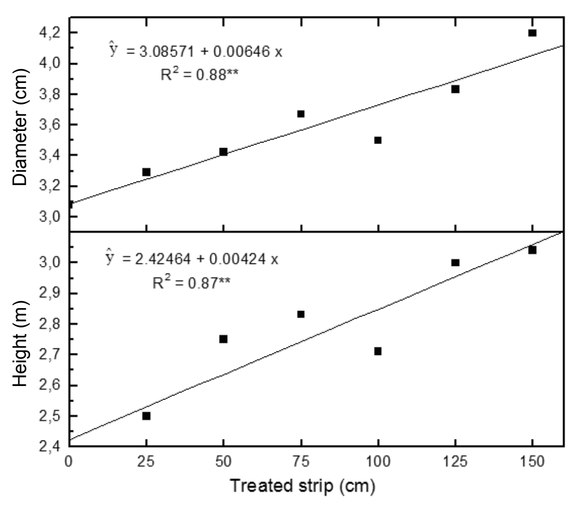

Figure 2. Response of eucalyptus plant diameter and height to weed herbicide-treated strip width. Altinópolis County, São Paulo State, Brazil.

Although trees grown with weed-free strips produced the maximum heights and stem diameters in our experiments, completely weed-free plantation is rarely necessary for normal tree growth (SCHUMANN et al., 1994). Such regimes tend to be expensive to maintain in terms of herbicide usage. In addition, lack of ground flora may be deemed to be aesthetically poor and make the soil more susceptible to erosion and leaching. In our experiments, all other inter-row management options reduced tree height and stem diameter, but not to an unacceptable degree. However, it is important to control weeds, avoiding competition between plants, until canopy closure begins and trees start to dominate or suppress weed growth (WILLOUGHBY; DEWAR, 1995).

Dry matter, leaf area and chlorophyll content

Araraquara - Leaf dry matter showed a proportional increase with width of weed-free strips. Leaf dry matter in the weed-free treatment was 78% higher than in the control treatments. Branch and stem dry matter results were similar, whereas the weed-free treatments were 83% for branches and 76% for stem, which is higher than the control treatment (Figure 3). The eucalyptus leaf area increased with weed-free strip width starting at 75 cm. The leaf area of plants with 150-cm width strips was 80% higher than in the control treatment. Chlorophyll content showed higher values with strips of 75 cm and wider (Figure 4).

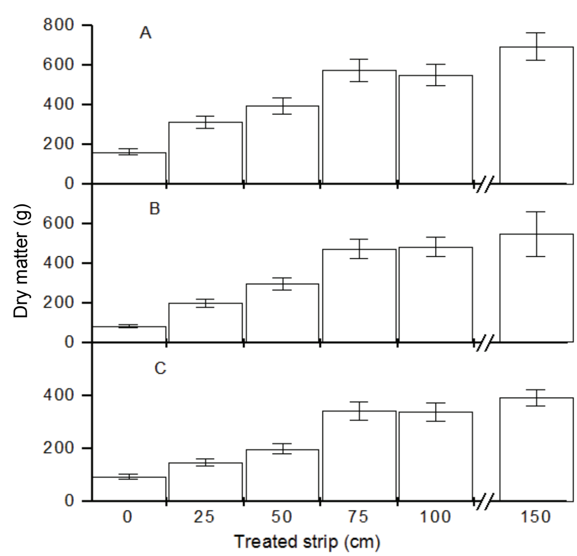

Figure 3. Leaf (A), branch (B) and stem (C) dry matter of *E. grandis* plants at 150 days, Araraquara County, São Paulo State, Brazil (means ± sde).

Altinópolis - Leaf dry matter did not show any differences until strip widths reached 75 cm. An increase in leaf dry weight was observed for higher-width strips. For branch dry matter, this difference was observed from 100 cm onwards. The weed-free treatment had branch dry matter 71% higher than the control treatment. The stem dry matter showed a difference of 39% between the weed-free and control treatment (Figure 5).

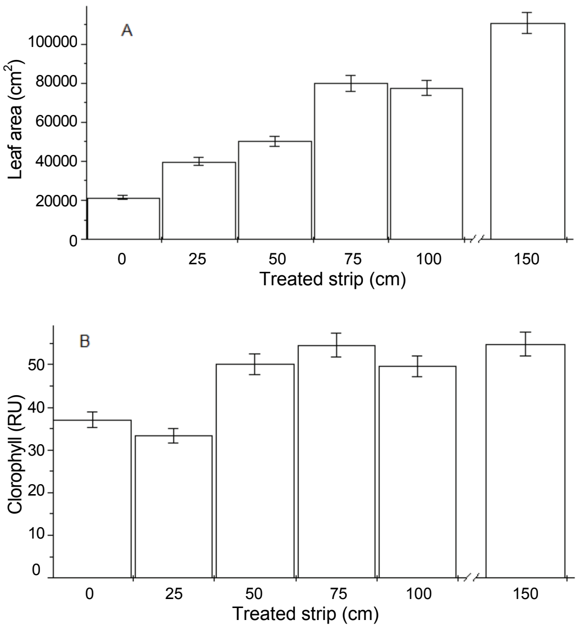

Figure 4. Leaf area (A) and chlorophyll content (B) of *E. grandis* plants at 150 days, Araraquara County, São Paulo State, Brazil (means ± sde).

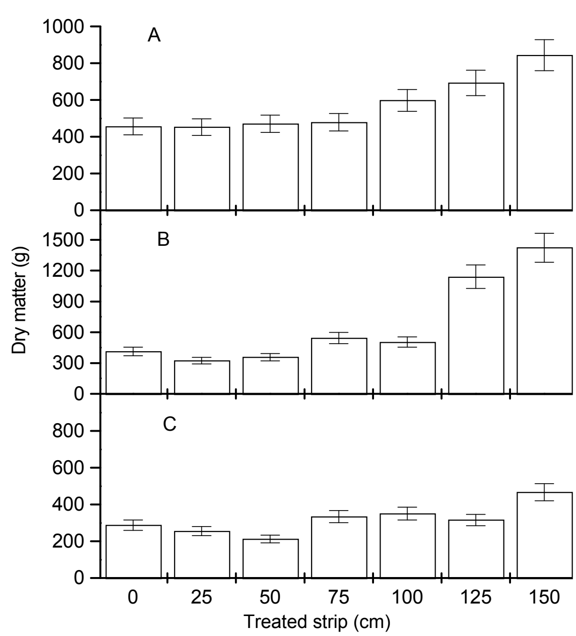

Figure 5. Leaf (A), branch (B) and stem (C) dry masses of *E. grandis* plants at 150 days, Altinópolis County, São Paulo State, Brazil (means ± sde).

Leaf area was the growth parameter most sensitive to weed interference. The plants of weeded treatment had 47% the leaf area of the weed-free treatment. Total chlorophyll content was unaffected until strip widths reached 75 cm (Figure 6).

Willoughby and McDonald (1999) determined that stem diameter correlated positively with dry matter production in conifers. We observed an increase in leaf, branch and stem dry matter correlated with an increase in the width of the weed-free strips. The critical advantage in establishing trees with weed-free areas and inter-row management, compared with no vegetation management, may be that canopy closure may occur several years earlier.

This study showed that with an infestation of *Panicum maximum* or *Rhynchelytrum repens* as the main species, it was necessary to have a treated strip of 75 cm in width to prevent weed interference with the initial growth of *Eucalyptus grandis*. Toledo et al. (2000a), studied the width of control strips (*U. decumbens* as the main weed species) kept during the first 12 months at 0, 25, 50, 100, 125 and 150 cm on each side of the eucalyptus row and increased these widths throughout the experiment; i.e., 25 to 150, 25-50-150, 50-150, 50-125-150, 100-125-150, 100-150 and 125-150 cm on each side of the eucalyptus row during the first year. They observed that *E. grandis* x *E. urophylla* that had grown both in the constant and increasing-width control strips with widths of at least 100 cm showed higher diameter, height and absolute growth in diameter and height. These results led the authors to conclude that the minimum control strip width should be 100 cm on each side of the eucalyptus row to prevent weed interference. In another study, with *U. decumbens* and *S. latifolia* as the main weed species, Toledo et al. (2003) verified that it was necessary to have at least 100-cm constant strips or 50-cm increasing control strips to keep *E. grandis* x *E. urophylla* plants free of weed interference.

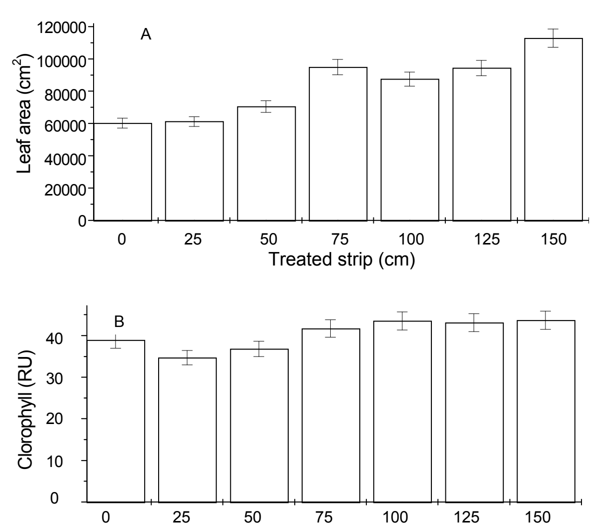

Figure 6. Leaf area (A) and chlorophyll content (B) of *E. grandis* plants at 150 days, Altinópolis County, São Paulo State, Brazil (means ± sde).

Conclusion

A minimum of 75 cm of treated strip was required to minimise weed interference with eucalyptus plants' development where mains weed were *Panicum maximum* and *Rhynchelytrum repens*.

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