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Research Article

Influence of the stump diameter and height on the growth and vigor of eucalyptus sprouts[1]

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ABSTRACT

Forest stands managed with the coppicing technique tend to display a decreased production in subsequent rotations, demanding high stump sprouting rates, so that the planting succeeds. This study aimed to assess the vigour of eucalyptus sprouts on the basis of stumps diameter and height. The number of sprouts and height of the highest sprout were assessed regarding the stumps diameter, providing the following treatments: stumps smaller than 12 cm in diameter; from 12 to 15 cm; from 15.1 to 18 cm; and larger than 18 cm. The number of sprouts was also assessed as a function of the cutting height of the stumps, providing the following treatments: stumps near the ground and at 5, 10 and 15 cm above the ground. The diameter of the stumps did not influence the amount of sprouts, but exerted influence on the height of the highest sprout after 120 and 150 days of re-sprouting. The stump height had a great influence on the number of sprouts, indicating that, despite reducing the volume of timber harvested, the highest stumps provided expressive gains in the stand regeneration. The cutting height and stumps diameter influence the sprouting vigour of eucalyptus clones managed by the coppicing system.

KEYWORDS: *Eucalyptus urograndis*, coppicing, reforestation, stump regeneration.

RESUMO

Influência do diâmetro e altura das cepas no crescimento e vigor de brotações de eucalipto

Povoamentos manejados pelo regime de talhadia tendem a apresentar decréscimo de produtividade nas rotações subsequentes, o que exige altas taxas de brotação das cepas para o sucesso da condução do plantio. Objetivou-se avaliar o vigor de brotações de eucalipto, em função do diâmetro e altura das cepas. Foram avaliadas a quantidade de brotações e a altura do maior broto, em função do diâmetro das cepas, configurando os seguintes tratamentos: cepas menores que 12 cm de diâmetro; de 12 a 15 cm; de 15,1 a 18 cm; e maiores que 18 cm. Avaliou-se, ainda, o quantitativo de brotação em função da altura de corte das cepas, configurando os seguintes tratamentos: cepas rentes ao solo e a 5; 10; e 15 cm do solo. O diâmetro das cepas não influenciou na quantidade de brotações, mas mostrou influência quanto à altura do maior broto, com 120 e 150 dias de rebrota. A altura das cepas mostrou grande influência na quantidade de brotos, indicando que cepas mais altas, apesar de reduzir o volume de madeira colhida, proporcionam ganho significativo na regeneração do povoamento. A altura de corte e o diâmetro das cepas influenciam no vigor da brotação de clones de eucalipto conduzidos pelo sistema de talhadia.

PALAVRAS-CHAVE: *Eucalyptus urograndis*, talhadia, reflorestamento, regeneração de brotos.

INTRODUCTION

The sprouting conduction of eucalyptus stumps was used as an option to regenerate forest stands during the 1970s and early 1980s; however, the forest stand reform began to be adopted due to a higher yield associated with other factors, despite its high cost (Embrapa 2008).

Studies oriented toward the coppicing system became scarce; nevertheless, the forest conduction method might be a favourable option for medium and small-scale farmers, perhaps assuring a high-quality supply of wood with a smaller production cost (Embrapa 2004).

The coppicing regime consists of conducting afforestation and directly depends on its trees re-sprouting capacity ensuing the cutting. It is an increasingly common practice in commercial eucalyptus cultivation (Azevedo et al. 2011). A coppicing regime may be more advantageous than the high forest regime, because the initial growth rate of sprouts is higher when their ages are compared, what may influence the time required to reach a maximum yield (Cacau et al. 2008). Coppicing offers several initial advantages, such as the presence of an already formed root system and the existence of reserve structures in the stump and roots, thereby allowing a fast plant development, in addition to reducing costs of

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soil preparation and planting operations (Costa 2018). However, the yield loss between rotations is the main disadvantage observed, with a reduction of 10 % from the first to the second rotation (Almado 2015).

The sprouting growth capacity and speed are aspects with direct influence on the yield of ensuing rotations. The sprouting capacity enables the regeneration of the forest stand, and the growth speed reflects on survival, in addition to promoting the homogeneity of future rotations (Guimarães et al. 1983).

Sprouting vigour can be determined by the height and diameter of the stumps (Luz et al. 2018). Larger diameter stumps tend to have better sprouting vigour, which, according to Mroz et al. (1985), could be related to the greater amount of carbohydrate reserves in the radicular system.

Trees with larger diameters have more developed root systems, increasing the ability of the soil to absorb water and nutrients (Oliveira et al. 2008), leading to the establishment of vigorous sprouting, that is, of greater height and diameter (Luz et al. 2018). However, Blake (1983) stresses that as the tree diameter widens due to increasing age, the sprouting vigour tends to decrease, what may be related to either the loss of vigour or to dormant buds.

Stump cutting height is another factor that interferes with the sprouting vigour, exerting a direct influence on the number of emerging sprouts. The recommendation in the coppicing system is to cut the tree leaving a stump of 10-15 cm high, considering that greater heights foster a larger number of buds (Embrapa 2004). On the other hand, larger stumps provide greater wood losses. According to Foelkel (2014), a loss of 0.4-0.7 % is estimated when the stump is 5-10 cm, while 1.5-2.0 % is lost when the stump exceeds 15 cm. Due to the diversity of clonal materials and sprouting capacities, studies have shown that the height may be reduced to 5 cm, depending on the material, thus increasing the use of wood in the factory (Chaves & Marrichi 2015).

The number of sprouts is an important characteristic for stump survival, due to the risks of injury or natural death of the stumps, such as death by competition. In addition to the aforementioned aspects, Geraldo Filho et al. (2020) report the existence of extrinsic factors to the physiological conditions of the sprouting, which may affect the growth of trees conducted by this management system.

Studies focused on the analysis of stump sprouting vigour after clearcutting are scarce in Brazil and concentrated up to the mid-1990s, when the adopted spacing varied little, the forest stands were mainly implemented by means of seeds, and the cutting age was around 7 years (Andrade et al. 1997, Camargo et al. 1997). Experiments with short rotation forestry system have been developed in a high trunk regime, mainly with eucalyptus (Melo 2016), but little is known about volumetric and biomass production under coppicing of these plantations. In this context, this study aimed to evaluate the sprouting vigor of a clonal *Eucalyptus* plantation.

MATERIAL AND METHODS

The experiment was carried out in a clonal *Eucalyptus* plantation (361 clones) with 3 x 3 m spacing, 9-years old, in Vitória da Conquista, Bahia state, Brazil (-14.86611ºS, -40.83944ºW and altitude of 923 m), from January to June 2016. According to the Köppen classification, the climate of the region is semi-arid, with an average annual rainfall of 925 mm and typical vegetation known as 'mata de cipó', or liana jungle.

The experiment installation took place after clearcutting the forest using a semi-mechanized system. The stump diameter and height, and their relation with sprouting vigour, were subsequently assessed.

Thus, stumps of approximately 10 cm high and different diameters were randomly selected to evaluate the stump diameter, providing the following treatments: stumps smaller than 12 cm in diameter; from 12 to 15 cm; from 15.1 to 18 cm; and larger than 18 cm. A total of 28 stumps were assessed, adding up to seven repetitions per treatment. The data regarding sprouting vigour (sprouts amount and height of the highest sprout) were collected monthly over a period of five months. The Assistat software (version 7.7 beta) was used to perform the Tukey test at 5 % of probability, to compare the means of the analyzed variables. Measuring tapes and rulers were used during the experiment, in order to measure the collected variables.

Next, stumps of different height classes were assessed maintaining the diameter pattern (15-18 cm). Four treatments were assessed in total, with five replications: 0 (stumps near the ground), 5, 10 and 15 cm high stumps. The variable used to assess the sprouting vigour was the number of sprouts emitted by the stumps. This variable was monthly quantified over a period of five months. The polynomial regression model was chosen to explain the variation in the number of shoots in relation to the number of days after cutting, considering the different height classes of the evaluated stumps. The data were processed using the Excel software (Office 16). Tapes and rulers were used during the experiment, in order to measure the variables.

RESULTS AND DISCUSSION

No meaningful difference, in relation to the amount of regenerated sprouts, was observed for the different diameter classes, with p = 0.05 using the the Tukey test (Table 1).

Such results corroborate a study carried out by Luz et al. (2018), which shows no positive correlation between stump diameter and number of sprouts, what may be related to a small variability among the diameter classes that were assessed. Simões et al. (1972) found similar results working with *Eucalyptus saligna*.

The amount of regenerated sprouts over the course of the first 30 days of assessment was high. This value decreased as the days went by, and later stabilized, maintaining an average of 7 sprouts per treatment by the end of 150 days. Carvalho et al. (2021) also observed a small reduction in the average number of shoots between the evaluations (second and third), which, according to them, may be explained by the competition among the shoots of each stump. The amount of shoots can also influence the shoot development, as there will be competition among them for growth resources, so size differences among shoots will increase if resources are limited, influencing the forest yield (Barros et al. 2017).

When studying the vigour of eucalyptus clone sprouts, Graça & Toth (1990) obtained a higher average of sprouts (6.5 sprouts per stump) in the remaining stumps with 8-12 cm in diameter, without further alteration in higher classes, diverging from the results found in this experiment.

The cutting season may have a major influence on the sprouting success. The cutting regarding this study was performed in January, which is characterized as being rainier and hotter in the region under study, constituting a condition which might have encouraged vigour in the assessed experiment. According to Ferrari et al. (2005), the time of the year that high-stem forests are cut influences the final regeneration result by means of stump sprouting, since extreme temperatures, absence of rain and excessive insolation reduce the number of sprouts and their quality.

Gonçalves et al. (2014) stress the relation between rainfall condition and sprout yield of *Eucalyptus* hybrids, highlighting its importance not only for establishing vigour, but also for the forest enterprise success.

Different diameter classes exerted no influence on the height of the highest sprout in the first month after cutting (using the Tukey test with p = 0.05); however, in the following months, there was a tendency of larger diameter stumps showing higher sprouts, what may be related to the number of stored reserves (Table 2).

Larger diameter stumps tend to display a more developed radicular system, promoting water and nutrient absorption, thus boosting growth rate in the shoots of the sprouts, with direct influence on vigour, mainly as to the height of the sprout shoot. A study conducted by Neelay et al. (1984) with *Eucalyptus tereticornis* concluded that trees below 4 cm in diameter display smaller values in relation to the sprout height, when compared to larger diameter trees, coinciding with the results found in the present study.

Table 1. Comparison among the averages referring to amount of sprouts of the treatments with different diameter classes.

Treatments	Amount of sprouts				
	30 days	60 days	90 days	120 days	150 days
< 12 cm in diameter	20.57 a	8.5 a	7.71 a	7.85 a	6.71 a
12-15 cm in diameter	21.57 a	8.0 a	6.71 a	6.71 a	6.14 a
15.1-18 cm in diameter	23.14 a	13.0 a	11.28 a	10.42 a	8.71 a
> 18 cm in diameter	21.28 a	14.57 a	10.85 a	8.71 a	7.85 a
CV (%)	75.47	45.66	46.57	45.53	42.49

Table 2. Comparison among the averages referring to sprout height of the treatments with different diameter classes.

Treatments	Sprout height (cm)				
	30 days	60 days	90 days	120 days	150 days
< 12 cm in diameter	70.61 a	132.14 b	175.32 c	209.02 b	231.35 b
12-15 cm in diameter	94.16 a	160.28 ab	203.04 bc	211.32 b	249.45 b
15.1-18 cm in diameter	99.57 a	201.14 a	269.35 a	288.70 a	299.57 a
> 18 cm in diameter	90.84 a	162.81 ab	230.54 b	263.64 a	284.87 a
CV (%)	26.52	25.54	11.22	11.20	7.70

In assessing the relations between stump diameter and sprout height, Pereira et al. (1980) observed that 10-year-old eucalyptus stumps with 36.6 cm in diameter presented a better performance in relation to the height of the growing sprouts. The value of 36.6 cm in diameter even performed better for the three-age classes assessed (6.8 to10 years), with the latter having the best conditions to sprout growth.

The amount of sprouts was influenced by the height at which the stumps were cut, especially in the first 60 days. This number gradually decreased as the days went by, what may be partly related to a high competition rate. The polynomial regression model was efficient and the calculated coefficient of determination demonstrated that 27.09 % of the variation in the amount of sprouts was justified by the cutting height of stumps in the first treatment (< 12 cm in diameter), with a standard error equal to 39. This variation increased to 43.11 %, with standard error of 35.29, in the second treatment (12-15 cm in diameter), whereas 77.76 % and 78.97 % were observed in the third (15.1-18 cm in diameter) and fourth (> 18 cm in diameter) treatments for the coefficient of determination, and 30.08 and 29.45 for the standard error, respectively.

Stumps ranging from 10 to 15 cm in height performed better regarding the number of sprouts. Such results are in line with the study by Luz et al. (2018), who reported a positive correlation between the height of the eucalyptus stumps and the amount of sprouts. When studying different cutting heights for *Eucalyptus*, Nascimento Filho et al. (1983) obtained better results with 15 cm high stumps, whereas a height ranging from 5 to 10 cm above the ground was observed for *E. Citriodora.* However, very tall stumps generate production losses (Stroher et al. 2014).

The cutting height of stumps may influence their exposure to sunlight, as well as interfere with the sprouting capacity. According to Ferrari et al. (2005), the cutting height may have a positive effect on stump survival, since taller stumps cause a larger number of active buds, what increases the sprouting possibility.

The lowest averages for number of sprouts were found in stumps near the ground. According to Shackleton (2000), cutting heights close to the ground level promote the attack of wood degrading fungi and, at the same time, stumps with tall heights may reduce the vigour and growth of the sprouts.

The number of sprouts in all the treatments was more expressive in the first month of assessment, tending toward a gradual decrease, which may be partly related to the high competition rate, whereupon the number of sprouts remained more stable and less variable after 90 days (Figure 1).

Pereira et al. (1984) stressed the direct relation that exists between the cutting height and amount of regenerated sprouts, and observed that the increase in sprouting occurred in the first four months, with a decrease after this period for all the registered cutting heights, corroborating the results of the present study. While studying the sprouting conduction in different *Eucalyptus* species, Balloni et al. (1980) discovered that the cutting height is an important factor to be considered, mainly for trees of low sprouting capacity planted in places subjected to significant water deficiencies.

The lack of agreement existing among various authors and of recent studies on the ideal stump height for the coppicing system emphasize the importance of researches on this topic with species of interest (Embrapa 2004). Based on this study, it is recommended to control the stump height for the coppicing management in *Eucalyptus* plantations, in order to improve the shoots vigor and the yield index of the forest.

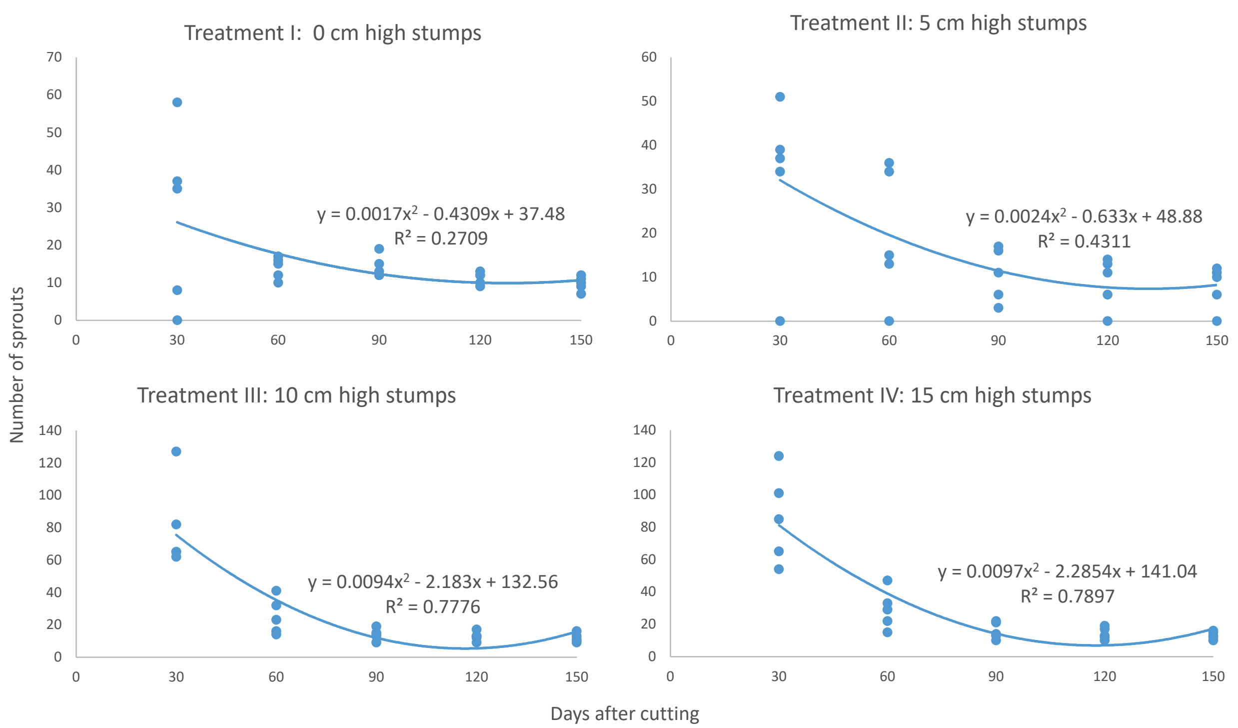

Figure 1. Comparative study of the number of eucalyptus sprouts every 30 days related to the cutting height of the stumps.

CONCLUSIONS

1. The stump diameter does not influence the number of eucalyptus sprouts;
2. The stump diameter influences the height of eucalyptus sprouting, with stumps above 15.1 cm in diameter generating higher sprouts;
3. Stumps ranging from 10 to 15 cm in height provide a larger number of sprouts emitted at the initial re-sprouting phase, with a tendency to stabilize over time.

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