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INITIAL GROWING AND MANAGEMENT IN EUCALYPTUS CLONES PLANTATIONS USING SLOW RELEASE FERTILIZERS

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Resumo

Cultivo inicial e manejo em plantios de clones de eucalipto utilizando fertilizantes de liberação lenta. Os adubos de liberação lenta disponibilizam os nutrientes ao longo do tempo, visando sincronizar a demanda da planta pelo nutriente, com o intuito de reduzir a perda deste para o ambiente. A utilização deste fertilizante pode promover benefícios, como redução da necessidade de adubação de cobertura e redução dos custos com mão de obra. Dessa forma, o objetivo deste trabalho foi testar a eficiência e as doses adequadas de P em fertilizante de liberação lenta (SRF) na adubação de base, bem como sua influência na adubação de cobertura em plantios de eucalipto. Foram testadas quatro doses de adubação de base (0, 85, 125 e 165 g de SRF planta^{-1}) e duas aplicações de adubação de cobertura (0 e 80g de N:P:K-20:00:20). Foram medidos altura, diâmetro a altura do solo, área do dossel, massa seca da parte aérea. Também foram calculadas as doses de máxima eficiência técnica para cada parâmetro. Houve interação entre altura e área do dossel, que demonstrou crescimento semelhante com e sem adubação de cobertura para todas as doses de SRF. Recomendamos o uso de SRF na dose de 125 g de SRF planta^{-1}, sem realizar adubação de cobertura.
Palavras chaves: Adubos inteligentes, Crescimento florestal, Nutrição florestal, Plantios florestais.

Abstract

The slow release fertilizers, release the nutrients over time, aiming to synchronize with the plant's demand for the nutrient, with the reduction of its loss to the environment. The use of this fertilizer can promote benefits, such as reducing the need for top dressing and reducing labor costs. The objective of this work was to test the efficiency and adequ ate doses of P in slow release fertilizer (SRF) in base fertilization, as well their influence in cover fertilization in eucalyptus plantations. Was tested four doses of base fertilization (0, 85, 125 e 165 g of SRF plant^{-1} applied with SRF) and two applications of cover fertilizer (0 and 80g of N:P:K-20:00:20). Height, diameter at ground height, canopy area, dry mass of the aerial part was measured. The dose of maximum technical efficiency was calculated. There was an interaction between height and canopy area, which demonstrated similar growth with and without cover fertilization for all doses of SRF. We recommend the use SRF at a dose of 125 g of SRF plant^{-1}, without performing cover fertilizer.
Keyword: Smart fertilizers, Forest growth, Forest nutrition, Forest plantations.

INTRODUCTION

The Brazilian planted tree sector contributes around 1.2% of the country's GDP, such as the main planted forest matrix is of the eucalyptus genus, totaling around 7.53 million planted hectares (IBÁ, 2022). Maintaining forest productivity depends on different factors, and forest management is one of the main strategies used to increase the volume of wood produced (CUNHA *et al.*, 2021). Furthermore, the use of fertilizers, when use correctly, can contribute to reducing greenhouse gas emissions by increasing efficiency in agricultural production and reducing deforestation of native forests which are important carbon sinks (MACEDO *et al.*, 2012; CUNHA *et al.*, 2021). In this context, it is important to know the different sources of existing fertilizers and the different management opportunities they can provide in eucalyptus plantations (ZHENG *et al.* 2016).

One of the technologies in development worldwide is slow-release fertilizer (SRF), which releases nutrients to the plant over time, reducing nutrient loss through leaching and through nitrogen volatility (CUNHA, *et al.* 2021). SRF improves plant growth conditions, because it provides nutrients based on demand, in addition to reducing stress and specific toxicity resulting from the excessive supply of nutrients in the root zones (GUO *et al.*, 2016). Because of their benefits, these fertilizers have expanded their share of the world market, with a growth rate of 6.5%, between 2014 and 2019 (FU *et al.*, 2019). Brazil, they are used mainly for agricultural crops, in there are studies for crops such as coffee and rice, related to reducing nutrient loss, improving crop quality, and increasing productivity (ZHENG *et al.*, 2016; GUO *et al.*, 2017).

According to Silva *et al.*, (2015) and Lang *et al.*, (2010), the use of SRF in the planting of forest species can reduce the need for cover fertilization (top dressing) and promote gains in growth. These benefits make it possible to reduce plantation maintenance costs, which are concentrated in the early years (BRANCALION *et al.*, 2017). Silva *et al.*, (2015), who used SRF encapsulated with elemental sulfur and coated with non-water-soluble organic polymers plantations in the base fertilization of eucalyptus hybrids; they verified a reduction in the need for cover fertilization and, consequently, a reduction in maintenance expenses.

Thus, the objective of this study was to test (1) the efficiency and adequate doses of SRF (fertilizer coated with elemental sulfur and coated with non-water soluble organic polymers) in base fertilization (BF), and (2) the impact of SRF on the need for cover fertilization (CF). The experiments were carried out on seedlings of a hybrid *Eucalyptus urophylla* x (*E. camaldulensis* × *E. grandis*).

MATERIAL AND METHODS

The experimental area is located in the south of the state of Minas Gerais (21°13'14.033" S and 44°58'0.232″ W), with a Cwb-type climate, according to the classification proposed by Köppen (ALVARES *et al.*, 2013). The average annual temperature is 19.6 °C, varying between 14.8 °C and 26.5 ºC in the coldest and hottest months, respectively. The average annual precipitation is 1511 mm, varying from 16.9 mm in the driest month to 293.9 mm in the wettest month. The average annual relative humidity is 76.2% and the total annual evaporation is 901.1 mm (INMET, 2019).

Planting was carried out in a dystrophic Red Latosol (Oxisol) at 919 m above sea level. The physical and chemical analyzes of the soil were determined according to Teixeira *et al.*, (2017) and Silva (2009) (Table 1).

Table 1: Results of the chemical and physical analysis of the dystrophic Red Latosol.
Tabela 1: Resultados das análises química e física do Latossolo Vermelho distrófico.

Attribute	Results	Attribute	Results
pH (H_2O)	4.80	m (%)	0.00
P (mg dm^{-3})	1.71	MO (g Kg^{-1})	8.60
K (mg dm^{-3})	0.06	Zn (mg dm^{-3})	0.30
Ca^{2+} ($cmol_c$ dm^{-3})	0.40	Fe (mg dm^{-3})	17.17
Mg^{2+} ($cmol_c$ dm^{-3})	0.10	Mn (mg dm^{-3})	1.80
AL^{3+} ($cmol_c$ dm^{-3})	0.00	Cu (mg dm^{-3})	1.43
H +Al ($cmol_c$ dm^{-3})	5.05	B (mg dm^{-3})	0.38
SB ($cmol_c$ dm^{-3})	0.55	S (mg dm^{-3})	20.70
(t) ($cmol_c$ dm^{-3})	0.55	Sand (dag kg^{-1})	160.00
(T) ($cmol_c$ dm^{-3})	5.60	Silt (dag kg^{-1})	200.00
V (%)	10.00	Clay (dag kg^{-1})	640.00

SB: sum of base, t: effective CTC, T: cation exchange capacity, V: base saturation, m: aluminum saturation index.
SB: soma da base, t: CTC efetivo, T: capacidade de troca catiônica, V: saturação por base, m: índice de saturação de alumínio.

In the experimental area, it was necessary to correct the soil with the application of dolomitic limestone to supply Ca and Mg at a proportion of 750 kg^{-1} ha^{-1} of limestone (70% PRNT), according to the formula proposed by Raij (2011). The soil preparation consisted of harrowing the total area, and the periodic manual control of ants and weeds. The fertilizers were applied manually at planting, with calibrated containers simulating commercial application after soil preparation and plot demarcation.

The seedlings of the hybrid *E. urophylla* x (*E. camaldulensis* × *E. grandis*) were planted at a spacing of 3 × 2 m, in February 2019. The monthly minimum and maximum average temperatures and precipitation occurring during the year are shown in Figure 1.

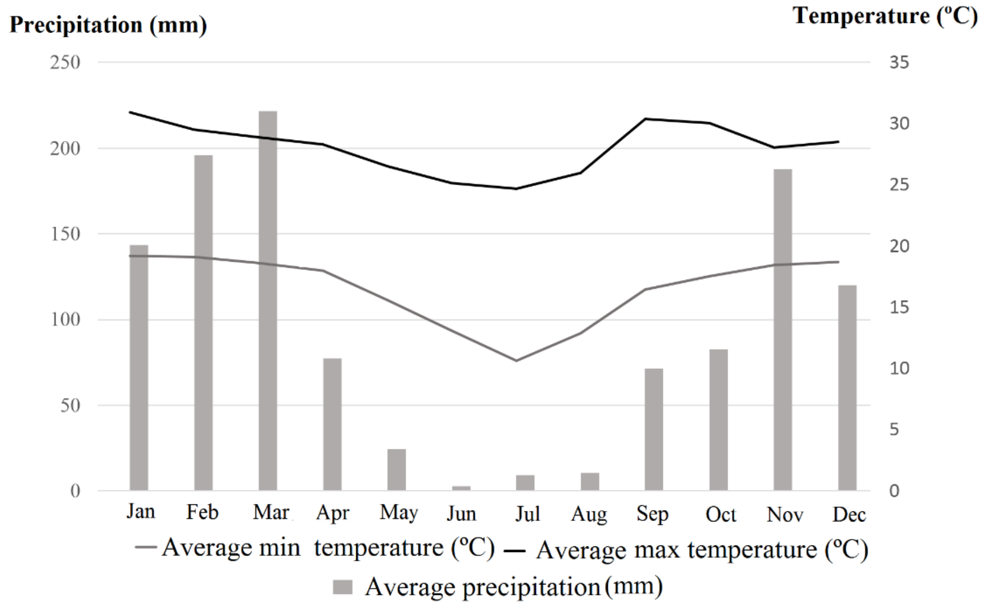

Figure 1: Monthly averages of minimum and maximum temperature and precipitation in the Lavras region in 2019.
Figura 1: Médias mensais de temperatura mínima e máxima e precipitação na região de Lavras em 2019.

The experiment was installed in a 4 × 2 factorial scheme (four doses of BF and two doses of CF) in a complete randomized block design with four replications and three plants per plot. The seedlings were distributed in five planting lines, with two border plants at the beginning and end of each line.

The doses used (Table 2) were based on the recommendation for eucalyptus fertilization used in Minas Gerais (RIBEIRO *et al.*, 1999). The doses of the BF were calculated according to the levels of P_2O_5, corresponding to 27 g of P_2O_5 plant^{-1}. Applications of SRF encapsulated with elemental sulfur and coated with non-water soluble organic polymers (11% N, 22% P_2O_5, 11% K2O, 12.29% S, 0.35% B, 0.30% Cu, and 0.30% Zn), with nutrient release for up to six months, consisted of doses of 0, 85, 125, and 165 g plants^{-1}, which corresponded to 0, 18, 27, and 36 g of P_2O_5 plant^{-1}. Cover fertilization was performed at eight months, using doses of 0 and 80 g plants^{-1} of the formulated NPK 20-00-20.

Table 2: Doses and times of application of base fertilization and cover fertilization (CF) used in planting.
Tabela 2: Doses e épocas de aplicação da adubação de base e adubação de cobertura (CF) utilizadas no plantio.

Base fertilization			
Fertilizers	**Treatments**	**Dose of P_2O_5 (g plant^{-1})**	**Application**
SRF (11-22-11)	0 g SRF	0	Planting
	85 g SRF	18	Planting
	125 g SRF	27	Planting
	165 g SRF	36	Planting
Cover fertilization			
Fertilizers	**Treatments**	**Dose (g plant^{-1})**	**Application**
NPK (20-00-20)	0 CF	0	Without application
	1 CF	80	8 months after planting

SRF: slow-release fertilizer
SRF: adubo de liberação lenta,

The measured variables consisted of the height (H), diameter at ground height (DGH), and canopy area (CA) at two, four, six, eight, and ten months after planting. The CA was calculated according to Nieri *et al.*, (2018), based on the measurement of canopy diameter. This was determined in the field by measuring four canopy projection rays with the aid of a measuring tape. The centre of the tree trunk was taken as a reference point, and the distance to the canopy limit was measured at 90° angles. The area of the circle was then calculated using the averages of the four canopy projection rays, giving us CA. At ten months after planting, the dry mass of the aerial part (DMAP) of each tree was collected. The samples were washed in deionized water, packed in paper bags, and dried in an oven with forced air circulation, at 65 °C, for three days.

The levels of nutrients in the leaves were obtained through leaf chemical analysis. Samples of the dry leaf mass at each applied fertilizer dose were taken. To perform the chemical analysis, the samples were ground in a Willey mill with a 40-mesh sieve according to the methods described by Malavolta *et al.*, (1980). In order to estimate the accumulation of N, P, and K in the plant (stem, branches, and leaves), the content values of these elements were multiplied by the dry matter values of each treatment, according to the methodology of Prezotti e Bragança (2013).

The data obtained from the morphological characteristics were checked for normality of errors by the Shapiro-Wilk test, at a 5% probability of error. When checking for normality, analysis of variance (ANOVA) was performed. In cases of significant interaction, regression analyzes were carried out from splitting the treatments with different doses of SRF for each CF used, adjusting equations to the second degree, at the level of 5% probability of error. In case of interaction just in the different factors, regression analysis was performed at the level of 5% probability of error, for BF, and by the Tukey test at the level 5% probability of error, for CF, using R software version 4.3.1 (R Core Team, 2023).

To determine the best dose to be applied for SRF, the dose of maximum technical efficiency was calculated for the variables in which significant differences were verified by the F test at 5% error probability. For that, a linear regression analysis of the variables was performed as a function of the fertilizer doses that were tested, considering the significance of the coefficients at the level of 5% probability of error, and the determination coefficient (R^2). The DMTE of the variables of interest corresponded to the first derivative of the adjusted equations equal to zero. When the calculated value exceeded the maximum tested dose, the DMTE considered was 165 g SRF plant^{-1}.

In addition to analyzing plant growth over time, for each fertilizer level tested, a first-degree linear regression model was fitted using the 'lm' function. The model was trained on a dataset composed of 20 observations and was validated using the method of least squares. The evaluation of the efficiency of the models was carried out using the mean square of the error - RMSE (Equation 1) and the coefficient of determination (R^2). The analyses were performed in R software version 4.3.1 (R Core Team, 2023).

$$\text{RMSE} = \sqrt{\sum_{i=1}^{n} \frac{(Y_{obs} - Y_{est})^2}{n}} \qquad \text{Equation 1}$$

In which: RMSE: raiz do quadrado médio do erro; Y_{obs}= valor observado; Y_{est}= valor estimado; n= número total de pares de valores observados e estimados.

RESULTS

Height and DMAP showed an interaction between BF and CF (Figure 2). The treatments with and without CF showed similar height averages with the use of SRF, with a 125 g plant^{-1}, and the DMTE was 136 and 116 g plant^{-1}, respectively. For DMAP, the SRF with the use of CF was superior to the treatment without this fertilization, with respective DMTE of 107 and 165 g plant^{-1}. However, with the use of the 165 g plant^{-1} with SRF, top dressing was not essential for improved DMAP.

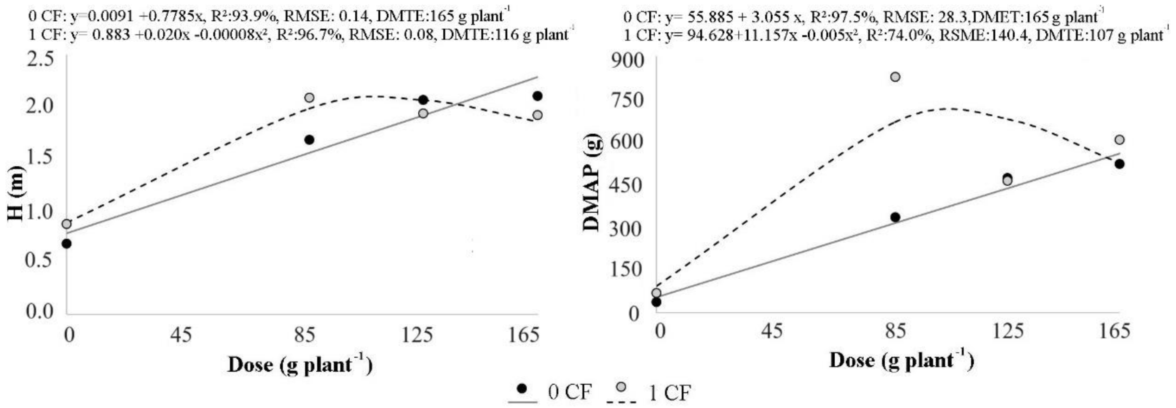

Figure 2: Effect of slow release fertilizer (SRF) and cover fertilization (CF), with their respective dose of maximum technical efficiency (DMTE), on increases in height (H) and dry mass of the aerial part (DMAP) of the hybrid *Eucalyptus urophylla* x (*E. camaldulensis* × *E. grandis*), at ten months of age.

Figura 2: Efeito do adubo de liberação lenta (ARF) e da adubação de cobertura (CF), com suas respectivas doses de máxima eficiência técnica (DMTE), nos aumentos de altura (H) e massa seca da parte aérea (DMAP) do híbrido *Eucalyptus urophylla* x (*E. camaldulensis* × *E. grandis*), aos dez meses de idade.

Regarding DGH and CA, the DMTE were 136 g plant^{-1} for both variables (Figure 3). For DGH, the use of CF was superior (25.09 mm) than without the cover fertilizer. There was no significant difference between treatments with and without the cover fertilizer, for CA, with an average of 1.13 m².

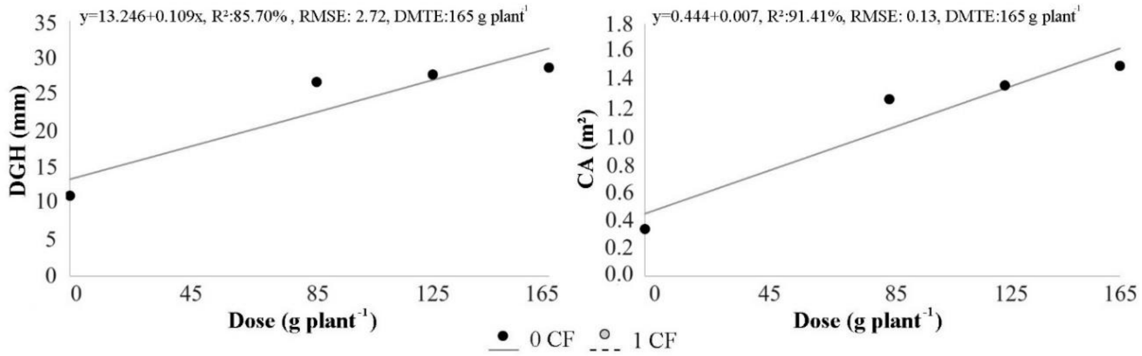

Figure 3: Effect of doses of slow-release fertilizer and cover fertilization (CF), with their respective dose of maximum technical efficiency (DMTE), on increases in the diameter at ground level (DGH) and canopy area (CA) of the hybrid *Eucalyptus urophylla* x (*E. camaldulensis* × *E. grandis*), at ten months of age.

Figura 3: Efeito das doses de adubo de liberação lenta e adubação de cobertura (CF), com suas respectivas doses de máxima eficiência técnica (DMTE), no aumento do diâmetro ao nível do solo (DGH) e da área do dossel (CA) do híbrido *Eucalyptus urophylla* x (*E. camaldulensis* × *E. grandis*), aos dez meses de idade.

It was observed that plant growth corresponded to linear growth, in which the higher the SRF dose, the greater the growth rate over time (Figure 4 and 5). For treatments fertilized with 85 g plant^{-1}, it was observed that the use of CF resulted in increased growth. For the dose of 125 g plant^{-1}, the growth rate between treatments with and without CF was similar. For the dose of 15 g plant^{-1}, the treatment without CF resulted in a higher growth rate.

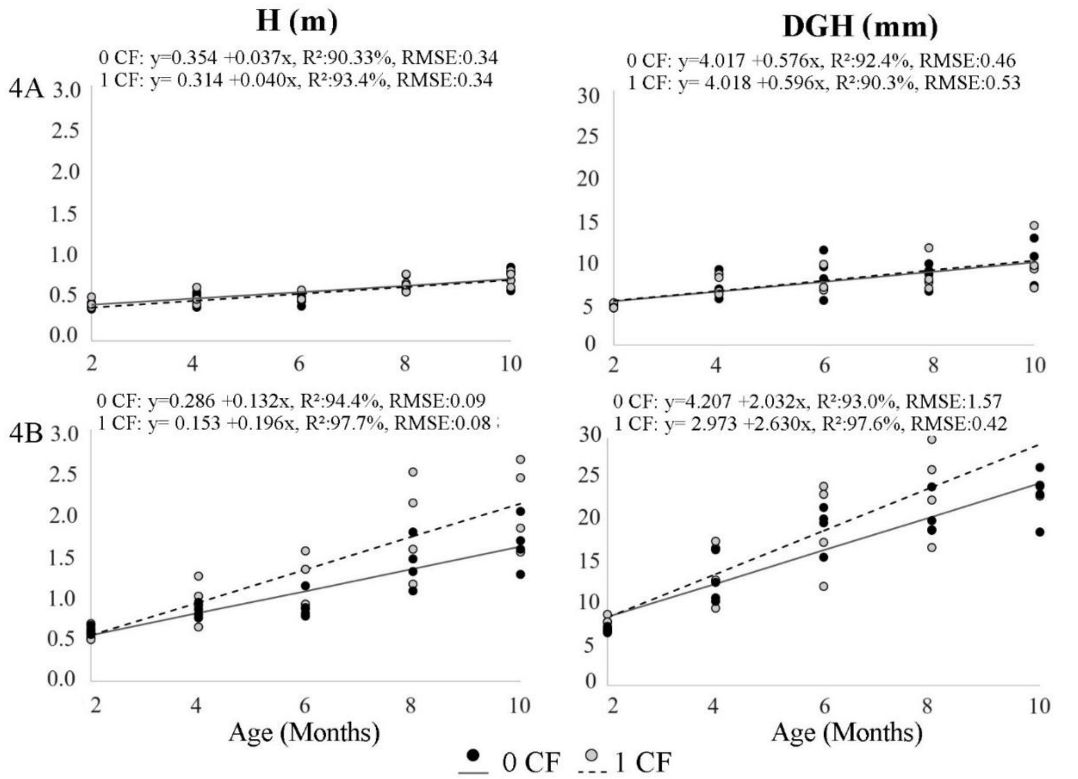

Figure 4: Growth rate in height (H) and diameter at ground height (DGH), in hybrids of E. urophylla x (E.camaldulensis × E. grandis), over the ten months of evaluation. Treatments 0 and 85 g plant-1 with slow realize fertilizer, correspond to Figures 4A and 4A, respectively.

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Figura 4: Taxa de crescimento em altura (H) e diâmetro à altura do solo (DGH), em híbridos de E. urophylla x (E. camaldulensis × E. grandis), ao longo dos dez meses de avaliação. Os tratamentos 0 e 85 g planta-1 de fertilizante de liberação lenta, correspondem às Figuras 4A e 4B, respectivamente.

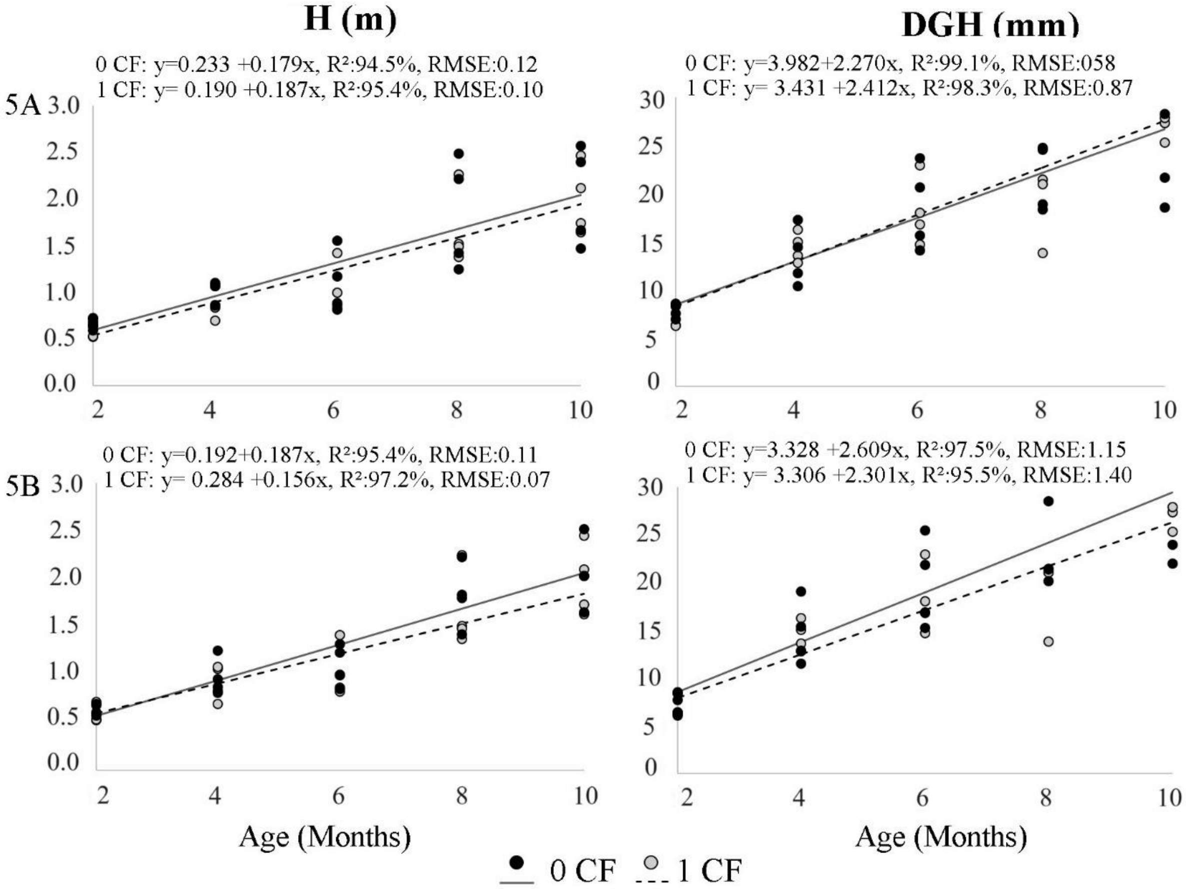

Figure 5: Growth rate in height (H) and diameter at ground height (DGH), in hybrids of E. urophylla x (E. camaldulensis × E. grandis), over the ten months of evaluation. Treatments 125 and 65 g plant-1 with slow realize fertilizer, correspond to Figures 5A and 5B, respectively.

Figura 5: Taxa de crescimento em altura (H) e diâmetro à altura do solo (DGH), em híbridos de E. urophylla x E.camaldulensis × E. grandis), ao longo dos dez meses de avaliação. Os tratamentos 125 e 165 g planta-1 de fertilizante de liberação lenta, correspondem às Figuras 5A e 5B, respectivamente.

When observing the results of the leaf analyses (Table 3), it was noted that the lowest levels of nutrients were found for treatments without BF. In general, when SRF doses increased, there was an increase in the concentration of nutrients. Among the micronutrients, there was a notable accumulation of B in the treatment fertilized with a dose of 165 g of SRF.

Table 3: Accumulation of macro and micronutrients in the dry mass of leaves corresponding to base (BF) and cover fertilization (CF), for Eucalyptus urophylla x (E. camaldulensis × E. grandis), at ten months of age.

Tabela 3: Acúmulo de macro e micronutrientes na massa seca das folhas correspondente à adubação de base (BF) e cobertura (CF), para Eucalyptus urophylla x (E. camaldulensis × E. grandis), aos dez meses de idade.

BF	CF	N	K	P	S	B	Cu	Zn
		g plant^{-1}				mg plant^{-1}		
0	0	443.2	220.6	37.1	49.4	383.4	329.8	616.4
0	1	906.4	477.0	55.6	453.2	387.4	576.4	791.1
18	0	4254.2	1867.7	294.0	415.1	2888.04	2576.8	4686.6
18	1	7377.7	3207.7	609.5	737.8	6639.94	4619.1	6319.2
27	0	3654.0	1922.1	285.5	361.6	8107.21	2416.9	4129.7
27	1	6370.1	2324.2	401.7	631.3	9928.24	3787.7	5222.4
36	0	4389.6	1688.3	363.6	571.4	11454.4	3636.3	4649.3
36	1	6756.4	3095.5	416.7	506.0	16519.0	3809.8	5238.5

DISCUSSION

The lowest amounts of growth occurred for the treatments without fertilization, for all variables, height, DGH, CA, and DMAP. This confirms that, like the findings of Marschner (2012), nutritional complementation is necessary for the good development of seedlings in tubes, regardless of the substrate. In addition, the growth for the variables evaluated showed positive quadratic behavior.

The treatments fertilized with SRF, with and without CF, did not present significant differences in height at ten months of age, which verified the possibility of planting eucalyptus clones with a single dose in the BF. Thus, to maximize the growth in height 165 g plant^{-1} could be applied, which would reduce the need for CF. Corroborating these results, Silva *et al.*, (2015) observed that a single dose of SRF (06:30:06), when planting eucalyptus clones, provided growth similar to the treatment with the application of soluble fertilizers at planting and top dressing. In addition, the authors found that the use of SRF presented less leaching of N and K, than the split fertilization, even at high doses.

In general, it appeared that the use of increasing doses of SRF, together with CF, provided a greater accumulation of DMAP, which agrees with the findings of Lima *et al.*, (2017), who reported an increase in shoot growth due to the second application of nitrogen. These results are related to the fact that the application of nitrogen at high doses tends to increase leaf biomass and, consequently, the leaf surface of the plants, which is directly related to the production of dry mass. Leaf biomass is an important and fundamental criterion for the vigor and the resistance capacity of the seedlings to adverse conditions, after planting in the field (LANG *et al.*, 2010).

Usually, plant fertilizers for base fertilization, have a low content of N and K, because of the dynamic of this nutrients in the soil, making CF essential to supply the demand for these nutrients over time. Because of its important role in physiological processes, vegetative growth, and resistance to adverse conditions (MARSCHNER (2012), all plants require nitrogen in greater quantities than other nutrients (DE JESUS *et al.*, 2012; MALAVOLTA 1980). However, when using the 165 g plant^{-1}, we recommend dispensing with CF for DMAP. At this does, SRF has satisfactory nitrogen and potassium levels, thus ensuring a similar increase in DMAP between treatments, with and without CF. Although this dose is higher than the recommended 125 g plant^{-1}, it appears that there is a cost saving by reducing the number of top dressing applications because labor is expensive (ZHENG *et al.*, 2016).

When observing the growth rate of the variables over time, it was observed that for treatments without fertilization, the addition of CF did not increase the growth trends of height and DGH. At the 18 g plant^{-1}, there was an increase in growth with the addition of top dressing. These results are related to the low levels of nutrients found in the dry leaf mass, which reflects the absence or low doses of nutrients applied in these treatments, when compared to the higher doses of SRF. This finding emphasizes the importance of fertilization in soils with low natural fertility to improve the establishment and increase the growth of high productivity forests (LIMA *et al.*, 2017).

For treatments fertilized with 125 g plant^{-1}, it was observed that there were no significant differences between seedling growth, with and without CF. This may be related to the higher levels of nutrients found in the dry leaf mass, which reinforces the efficiency of SRF in reducing the need for CF.

For the dosage of 36 g plant^{-1}, it was found that height and DGH showed a decrease in growth in the treatment with CF compared to the one without additional fertilization. This result may be linked to the high concentrations of macro and micronutrients found in the dry leaf mass, which may have caused the onset of toxicity and delayed seedling growth. Despite the physiological role of boron, copper, and zinc, the symptoms of toxicity in eucalyptus are not well known in the field, as they are less common than a deficiency of micronutrients (MALAVOLTA, 1980). However, Marschner (2012) indicated that one of the symptoms of copper toxicity is the reduction of growth, while boron toxicity manifests itself as a spotted chlorosis and then necrotic spots on the edges of the older leaves, which coincide with the leaf regions where there is greater transpiration.

When analyzing the effect of mineral fertilization on the nutrient content in the leaves of the seedlings, it is noted that, with increasing doses, there is an increase in the concentration of nutrients in the leaf. There is also an increase in the efficiency of absorption of nutrients P, S, B, Cu, and Zn, when CF is added. This corroborates the finding of Marschner (2012), who reported that the external ion concentration is one of the factors that affect root ion absorption.

Regarding BF with SRF, it was observed that the DMTE varied according to the variable analyzed. The values ranged from 107 to 165 g plant^{-1}, but we recommend using 125 g plant^{-1}. Furthermore, when observing the growth of variables over time, it was noted that the use of the 125 g plant^{-1} did not require top dressing, similar to the results of Silva *et al.* (2015).

Reducing cover fertilization is an opportunity to minimize the costs of planting forest species, mainly due to the dependence on the use of labor (ZHENG *et al.*, 2016; CUNHA *et al*., 2021). Although the sources of slow release fertilizers are more expensive than those of conventional release (GUO *et al.*, 2017), but Silva *et al.* (2015), found that application of the slow-release fertilizer at three months makes it possible to reduce the number of topdressing fertilizations, without decreasing productivity and without the risk of nutrient leaching. Studies of alternative fertilizers, which promote a reduction in fertilization, planting or coverage doses, are very important for the forestry sector, especially in the current world economic scenario, in which the supply of fertilizers has reduced (CALIGARIS *et al*., 2022).

Many authors reported better plant performance when using SRF over conventional immediate release fertilizers (SILVA *et al.*, 2015; YANG *et al.*, 2012). In addition, the SRF can be used as strategies for projects for the recovery of degraded areas, frost resistance, and greater competitiveness against weeds, as they provide greater initial growth than immediate release fertilizers, (CUNHA *et al.*, 2021; LANG *et al.*, 2011). Raymond *et al.* (2016) also found that nitrogen recovery by *P. taeda* applied by SRF is higher in relation to weeds than when using immediate release fertilizers.

In general, the use of SRF encapsulated with elemental sulfur and coated with non-water-soluble organic polymers guaranteed good growth, under the conditions employed in the present research, with mean of 1.95 m in ten months of age. In addition, its use is convenient, because it reduces labor costs, which are increasingly expensive. In addition to enhancing the absorption of nutrients over time by the plant, owing to its slow release characteristics, the gains in growth enable a gain in net revenue from forest plantations, as noted by Zheng *et al.*, (2016).

CONCLUSION

- The use of SRF, encapsulated with elemental sulfur and coated with non-water-soluble organic polymers, showed growth of a hybrid of *E. urophylla* x (*E. camaldulensis* × *E. grandis*) with quality at ten months of age.
- Base fertilization with 125 g of SRF plant^{-1} in a single dose is recommended for planting this species.

REFERENCES

ALVARES, C. A; STAPE, J. L.; SENTELHAS, P. C. M.; GONÇALVES, J. L.; SPAROVEK, G. Köppen's climate classification map for Brazil. Meteorologische. **Zeitschrift**, Stuttgart, v.22, p. 711-728, 2013.

BRANCALION, P. H. S; LAMB, D.; CECON, E.; BOUCHER, D.; HERBOHN, J.; STRASSBURG, D. P. Using markets to leverage investment in forest and landscape restoration in the tropics. **Forest Policy and Economy**, v.85, p.103–113, 2017.

CALIGARIS, B. S. A.; RANGEL, L. E. P.; POLIDORO, J. C.; FARIAS, P. I. V. A importância do Plano Nacional de Fertilizantes para o futuro do agronegócio e do Brasil. **Revista Política Agrícola**, Brasília, v.31, n. 1, p. 3-8, 2022.

CUNHA, F. L.; NIERI, E. M.; SANTOS, J. A.; ALMEIDA, R. S.; MELO, L. A.; VENTURIN, N. Uso dos adubos de liberação lenta no setor florestal. **Pesquisa Florestal Brasileira**, Colombo, v. 41, e201902063, p. 1-11, 2021.

DE JESUS, G. L. et al. Doses e fontes de nitrogênio na produtividade de eucalipto e nas frações da matéria orgânica em solo da região do cerrado de Minas Gerais. **Revista Brasileira de Ciência do Solo**, Viçosa, v. 36, n.1, p. 201-214, 2012.

TEIXEIRA, P. C.; DONAGEMMA, G. K.; FONTANA, A.; TEIXEIRA, W. G. **Manual de métodos de análise de solo**s. Rio de Janeiro: EMBRAPA Solos. 577 p. 201, 2017

FU, J. WANG; C. CHEN, X.; HUANG, Z.; CHEN. D. Classification research and types of slow controlled release fertilizers (SRFs) used - a review. **Communications in Soil Science and Plant Analysis**, Filadélfia, v. 49, n.:17, p. 219-2230, 2019.

GUO, C.; LI, P.; LU, J.; REN, T. CONG, R.; LI, X. Application of controlled-release urea in rice: Reducing environmental risk while increasing grain yield and improving nitrogen use efficiency**. Communications in Soil Science and Plant Analysis**, London, v.47, p.1176–1183, 2017.

IBÁ. Indústria Brasileira de Árvores. Relatório Ibá 2022. 100 p. Disponível em: < https://iba.org/datafiles/publicacoes/relatorios/relatorio-anual-iba2022-compactado.pdf>. Acesso em: 10 mar. 2023

INSTITUTO NACIONAL DE METEREOLOGIA. **Normais Climatológicas**. Disponível em:<http://www.inmet.gov.br/portal/ index.php?r=clima/normais>. Acesso em: 29 set. 2019.

LANG, A.; MALAVASI, U. C.; DECKER, V.; PEREZ, P. V.; MALAVASSI, A. Aplicação de fertilizante de liberação lenta no estabelecimento de mudas de ipê-roxo e angico-branco em área de domínio ciliar. **Floresta**, Curitiba, v.41, p. 271-276, 2011.

LIMA, A. S. F; GONÇALVES, J. L.; ROMANINI, J. R.; GONÇALVES, N. A. Efeitos da fertilização nos teores de micronutrientes em eucalipto em segunda rotação. **Revista ciência tecnologia a e ambiente**, Araras, v.5, p. 8-14, 2017.

MACEDO, M. N.; FRIES, R. S.; MORTON, C. M.; STICKLER, G. L; SHIMABUKURO, Y. E. Decoupling of deforestation and soy production in the southern Amazon during the late. **Proceedings of the National Academy of Sciences USA**, v.109: p.1341-1346, 2000.

MALAVOLTA, E. 1980. **Elementos de nutrição mineral de plantas**. São Paulo, Ceres 251p.

MARSCHNER, H. 2012. **Mineral nutrition of higher plants**. 3. ed. London: Academic Press, 89 p.

NIERI, E. M.; MACEDO, R. L. G.; MARTINS, T. G. V.; MELO, L. A.; VENTURIN, R. P.; VENTURIN, N. Comportamento silvicultural de espécies florestais em arranjo para integração pecuária floresta. **Floresta**, Curitiba, v.48, p.195-202, 2018.

PREZOTTI, L. C.; BRAGANÇA, S. M. Acúmulo de massa seca, N, P, e K em diferentes materiais genéticos de café conilon. **Coffee Science**, Lavras, v.8, p. 284-294, 2018.

RAIJ, B. Fertilidade do solo e manejo de nutrientes. Piracicaba: International Plant Nutrition Institute, 2011.

RAYMOND, J. E.; FOX, T. R.; STRAHM, B. D. Understanding the Fate of Applied Nitrogen in Pine Plantations of the Southeastern United States Using 15N Enriched Fertilizers. **Forests**, Basel, v. 7, n. 270, 2016.

R Core Team, 2023. **R: A language and environment for statistical computing**. R Foundation for Statistical Computing, Vienna, Austria 2023. Disponível em: <https://www.R-project.org>

RIBEIRO, A. C.; GUIMARÃES, P. T. G.; ALVAREZ, V. H. V. 1999. **Recomendações para o uso de corretivos e fertilizantes em Minas Gerais*: *5ª aproximação**. Viçosa: CFSEMG.

SILVA, F. C. 2009. **Manual de análises químicas de solos, plantas e fertilizantes**. 2. ed. Brasília, DF: EMBRAPA Informação Tecnológica.

SILVA, P. H. M.; POGGIANI, F.; SILVA, A. A.; NETO, J. P.; PAULA, R. C. Mortalidade, crescimento e solução do solo em eucalipto com aplicação de fertilizante de liberação lenta. **Cerne**, Lavras, v.21, p. 473-481, 2015.

YANG, T.; ZHANG, M.; LI YZ, F. X.; GENG, Y. Controlled Release Urea Improved Nitrogen Use Efficiency, Activities of Leaf Enzymes, and Rice Yield. **Soil Science Society of America Journal**, v.76: p.2307-2317, 2012.

ZHENG, W.; LIU, Z.; ZHANG, M.; ZHOU, H. Combining controlled-release urea and normal urea to improve the nitrogen use efficiency and yield under wheat-maize double cropping system. **Field Crops Research**, v.197, p. 52–62, 2016.