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Keywords:	Mineral Fertilization, NPK fertilizer, Candeia

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Initial growth of *Eremanthus erythropappus* (DC.) Macleish in function of planting and topdressing fertilization

Abstract

Growing demand for alpha-bisabolol oil extracted from *Eremanthus erythropappus* (DC.) Macleish, a Brazilian native tree, justifies its commercial plantations. However, its silviculture is relatively new and lacks information, especially about its nutritional aspects. It is the first study to focus on the field response of *E. erythropappus* to fertilization. We aimed to assess the effect of planting fertilization and topdressing on its initial growth. The experiment, conducted in Lavras, Brazil, consisted of six different fertilization treatments using different doses of nitrogen (N), phosphorus (P), and potassium (K), with the quantities based on soil analysis results and recommendations for other forest species. We designed the experiment in four randomized blocks using or not P at planting and application or not of N and K on top dressing, with the increase until 3X P dose when using N and K. Over 20 months, we evaluate the height (H) and base diameter (BD) and processed the data by ANOVA and Scott-Knott test ($p<0.07$). There was no response to any dose of phosphorus, while there was a positive response to the application of nitrogen and potassium, even without the application of phosphorus. The results indicate topdressing on *E. erythropappus* to maximize its growth and production.

Keywords: Mineral fertilization, NPK fertilizer, candeia.

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Introduction

Among the genus *Eremanthus* of the Asteraceae family, the specie *Eremanthus erythropappus* (DC.) Macleish stands out with large occurrence in Brazil. The main use is for fence posts and also for extracting its essential oil to obtain the Alfa-bisabolol component, highly appreciated in pharmaceutical industry. These are products that are valued on the local and international markets (Scolforo 2008, Oliveira et al. 2009).

E. erythropappus develops quickly in open fields, forming pure populations, with height varying from 2 to 10 m, and diameters up to 35 cm. It commonly grows in shallow, infertile and rocky soils, generally at altitudes between 900 and 1,800 m (Pérez et al. 2004). Its exploitation was mainly predatory through clear cuts in natural population. However, the increase in harsh environmental laws and actions to reinforce them, shifted the exploitation, which now demands a forest management plan.

With the rise in industrial demand for *E. erythropappus*, commercial planting has emerged as a potential alternative. However, the practice of *E. erythropappus* silviculture is still in its early stages, and there is a scarcity of scientific literature available on the subject. Most research encompasses native forest management (Pavan et al 2021), involving economic values (Carolina Souza Jarochinski e Silva et al. 2014), oil extraction (Longhi et al. 2009), oil yield (Galdino et al. 2006), as well as experiments of seedlings production (Melo et al. 2014, Silva et al. 2020).

Field experiments defined that spacing should be 3.0 m x 1.5 m to maximize production e reduce economic risks (Silva et al. 2014) and pruning is recommended (Páscoa et al. 2019). Nutritional management, Venturin et al. (2005), in a controlled environment, concluded that the nutrient limitation to support the growth of *E. erythropappus* is $P > N > S > Mg = B > Ca > K > Zn$, and the natural fertility level of Red-Yellow Latosol is unsuitable, requiring fertilization.

According to Silva et al. (2014), who followed commercial recommendations, a fertilizer comprising 100 g per pit of 4:14:8 NPK formulation with 0.4% zinc and a top dressing of 30 g of borax per plant was used. However, there is a dearth of data regarding the response of *E. erythropappus* to fertilization and nutrition in field conditions.

Given this knowledge gap in the nutrition of *E. erythropappus* plantations, this work aimed to assess the initial field growth in the function of planting and topdressing fertilization using nitrogen, phosphorus, and potassium.

Material and Methods

The experiment area was in Lavras from February 2019 to September 2020. The climate is the Cwa according to the Koppen climate classification, with humid

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temperate with dry winter, an average annual temperature of 19.4 ºC, varying between 15.8 °C and 22.1 ºC for July and February, respectively, and an average annual rainfall of 1,530 mm.

Seeds of *E. erythrop*appus collected from mother trees near Lavras, south of Minas Gerais state (MG), Brazil, were used in seedlings production in nurseries. The seedlings were apt for planting after six months.

The soil, classified as Red Latosol, was prepared by a total area harrowing. The seedlings were manually planted in February 2019 in pits measuring 20 cm in length, 20 cm in width, and 20 cm deep. The spacing was 2 m between rows and 1.5 m between plants.

To verify the growth response of *E. erythrop*appus, we tested six different fertilization combinations using nitrogen (N), phosphorus (P), and potassium (K), as shown in Table 1. To supply phosphorus, we used a simple superphosphate fertilizer (P_20_5 – 17%) mixed with the soil at planting. For nitrogen and potassium, we used a fertilizer formulated with 20:0:20, containing 20% of N (NH_4) and 20% of K_2O, as a top-dressing fertilization divided into two applications during the rainy season.

[HERE THE TABLE 1]

The 1P dose of 100 g per plant was established based on the minimum amount of phosphorus applied in the planting fertilization of *Eucalyptus* spp. (Guimarães et al. 1999). As for the 1N and 1K doses of 80 g per plant, they were determined according to the soil analysis results (Table 2), following the recommendation for *Eucalyptus* spp. (Guimarães et al. 1999) due to the absence of specific recommendations for *E. erythropappus*.

The N and K applications were in December 2019, after the beginning of the rainy season, and the second in February 2020. It is noteworthy that the initial soil conditions given through soil analysis before the experiment show low phosphorus levels (1.22 mg dm^{-3}).

[HERE THE TABLE 2]

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The experiment used a randomized block design, with six treatments, four replications, and five plants per block. We divided the seedlings into two size classes, with larger seedlings allocated in blocks 1 and 2 and smaller seedlings in blocks 3 and 4, meeting the premises for experimentation.

Throughout the experimental period, silvicultural activities necessary for the maintenance and protection of the seedlings were carried out. The seedlings were treated with fipronil-based termite killer before planting by immersing the root system in the fipronil solution diluted in water according to the manufacturer's specifications; the control of leaf-cutting ants was carried out using granulated sulfuramide-based baits in a radius of up to 100 m around the plantation; irrigation in the first months; the irrigation was performed by applying 5 liters of water per plant at planting, complementary irrigations were performed when the need was identified based on the visual aspects of the plants.

To control weeds, various methods were used that together allowed for greater efficiency. A 50 cm radius around the seedling was weeded manually with a hoe and a pre-emergence herbicide based on oxyfluorfem was applied. In addition to control the area around the seedling, mechanized mowing was also performed on the total site followed by applying a post-emergent, non-selective, systemic herbicide based on glyphosate.

We measured the survival, height (H), and base diameter (BD) of seedlings over 20 months. We use a ruler to measure the height, and a digital caliper (precision 0.2 mm) to measure the base diameter at the root collar height.

To assess the effect of fertilization analyzes of variance were carried out. The means were compared through the Scott-Knott test at 7% probability on software Sisvar (Ferreira 2019).

Results

Survival was unaffected by fertilization, maintaining an average of 90% across the test. Anova showed a statistically significant difference ($p<0.07$) in the mean height (H) and base diameter (BD) for the treatments tested in all evaluations (Table 3). All CV (%) varied from 7.9 to 20.3, demonstrating good experimental precision.

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[HERE TABLE 3]

When comparing the *E. erythropappus* seedling growth over time for each treatment, we observed that during the dry season (May to October/19) before the topdressing fertilization (December/19 and February/20), there was no clear distinction between growth patterns among the treatments (Figures 1 and 2).

[HERE THE FIG. 1]

[HERE THE FIG. 2]

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After October 2019, with the rainy season starting, there was a shift in the height and base diameter growth patterns. There was a clear separation into groups, where 1N-0P-1K was objectively better than 0N-1P-0K and 0N-0P-0K in both H and BD. Other treatments using variations of topdressing fertilization and larger phosphorus applications were between those extremes.

These differences, displayed in Table 4, show the separation of the treatments into groups starting from 12 months, a group with the application of N and K as topdressing fertilization, which presents a superior growth in H and BD, and a group formed by a single dose of P (0N-1P-0K) and the control (0N-0P-0K) with no statistical difference.

[HERE THE TABLE 4]

Discussion

Our study revealed that fertilization did not have a significant impact on survival, agreeing with the observations of Ferreira et al. (2020), where the greatest impact on survival was related to herbicide use. Although our findings suggest that the fertilization treatments tested did not influence *E. erythropappus* seedlings' survival, it can still be employed as a method to enhance plant growth and productivity.

The high survival rate of 90% indicates that *E. erythropappus* seedlings can tolerate unfavorable environmental conditions, such as a six-month drought period after planting. It is worth noting that *E. erythropappus*, with a 90% survival rate, is a suitable species for commercial forests (Sturion and Bellote 2000) and restoration projects (Almeida and Sánchez 2005), where a 10% mortality rate is considered acceptable.

As mentioned, there were six months of drought after planting the seedlings in the field, with an average rainfall of 34.7 mm from April/19 to June/19 and 10.3 mm from July/19 to September/19. The start of the rainy season, from October/19 to December/19, with an average of 167.7 mm, coincides with the treatment's differentiation for height (Figure 1). The response of DB is noticeable after February/20 when finished the topdressing fertilization (Figure 2).

There was no apparent difference among *E. erythropappus* seedlings during the dry season despite the elevated doses of P in soil with low concentrations of this nutrient. These observations directly contrast with the high importance of P in the growth of *E. erythropappus* described by Venturin et al. (2005). These differences, further characterized in Table 4, depict two main phenomena: Fertilization with N and K results in gains for H and BD disregarding the phosphorus' amount; the sole use of phosphorus did not result in H and BD different from the control (0N-0P-0K).

We can draw the hypothesis that *E. erythropappus* is less dependent on phosphorous than previously thought. This justifies the no response to P's application, where species sensible to phosphorus fertilization have a fast response, as observed for *Toona ciliata* M. Roem. (Nieri et al. 2019), *Acrocarpus fraxinifolius* Arn. (Araujo et al. 2022), *Cordia thrichotoma* (Vell.) Arráb. ex Steud. (Cunha et al. 2021) and several other rainforest species native to Brazil (Silva et al. 2022).

Another reasonable explanation for the no response to phosphorus is that with the lack of water during the dry season, the nutrient would stay absorbed by the soil, unavailable for the plant. With an increase in water availability after October/19, the process of cationic interaction took place, increasing the availability of P for the plants because of the amount of this nutrient compartmentalized in the soil. This hypothesis corroborates with the observations of Yao et al. (2023) that seasonal variation and nutritional management alter the soil P fraction concentration.

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The fast growth response to N and K applications relies on the fact that these nutrients are readily available to the plant when it is in more demand, during the growing season, in wet soil condition. Venturin et al. (2005) place N as the second most limiting nutrient for the growth of *E. erythropappus* because it is essential in the synthesis of proteins and nucleic acids (Taiz et al. 2015). According to Gazola et al. (2019), the simultaneous application of N and K increases the efficiency of N in *Eucalyptus* ssp., the same could happen in the top-dressing used in *E. erythropappus*.

The naturally poor soil in which *E. erythropappus* are found suggests an environmental adaptation to this condition and reveals a low nutritional requirement. Good nutritional management by fertilization can improve growth in *E. erythropappus* especially utilizing N and K, as demonstrated in our results and corroborated by Venturin et al. (2005). A more thorough investigation into phosphorous fertilization is needed, especially analyzing the relationship between it and water availability. Further studies are necessary to assess additional parameters and gain a more comprehensive understanding of the effects of fertilization on *E. erythropappus*, particularly in terms of nutritional aspects.

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Conclusion

There was no response of phosphorus fertilization on *E. erythropappus*. Topdressing fertilization using 80 g of nitrogen and potassium in a fertilizer formulated with 20:0:20, containing 20% of N (NH_4) and 20% of K_2O showed superior results in height and base diameter of *E. erythropappus* at 20 months old.

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Figures' caption list

Figure 1- Height growth curve of *Eremanthus erythropappus* seedlings in response to the different fertilization over 20 months after planting in Lavras-MG, Brazil.

Figure 2 – Base diameter growth curve of *Eremanthus erythropappus* seedlings in response to the different fertilization over 20 months after planting in Lavras-MG, Brazil.

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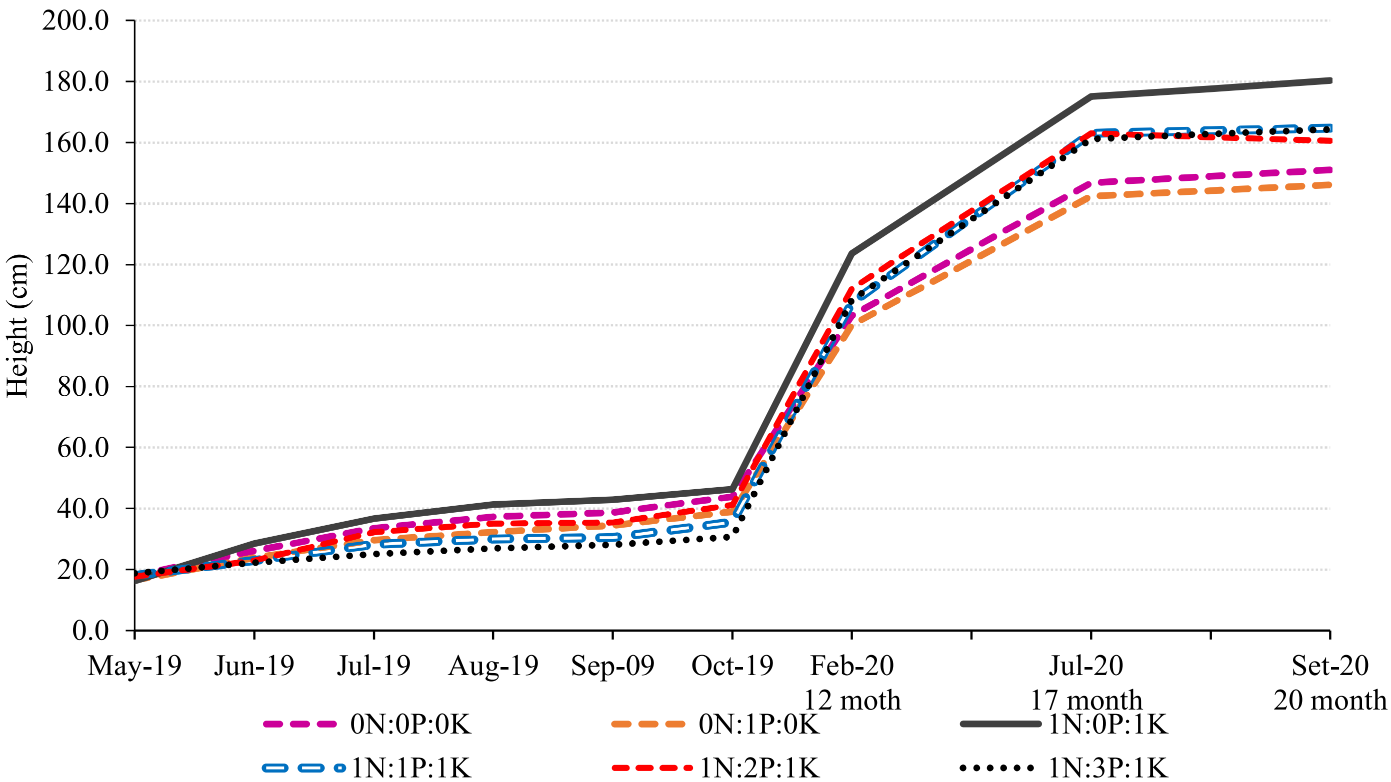
200.0
180.0
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
Height (cm)
May-19
Jun-19
Jul-19
Aug-19
Sep-09
Oct-19
Feb-20
12 moth
Jul-20
17 month
Set-20
20 month
0N:0P:0K
0N:1P:0K
1N:0P:1K
1N:1P:1K
1N:2P:1K
1N:3P:1K

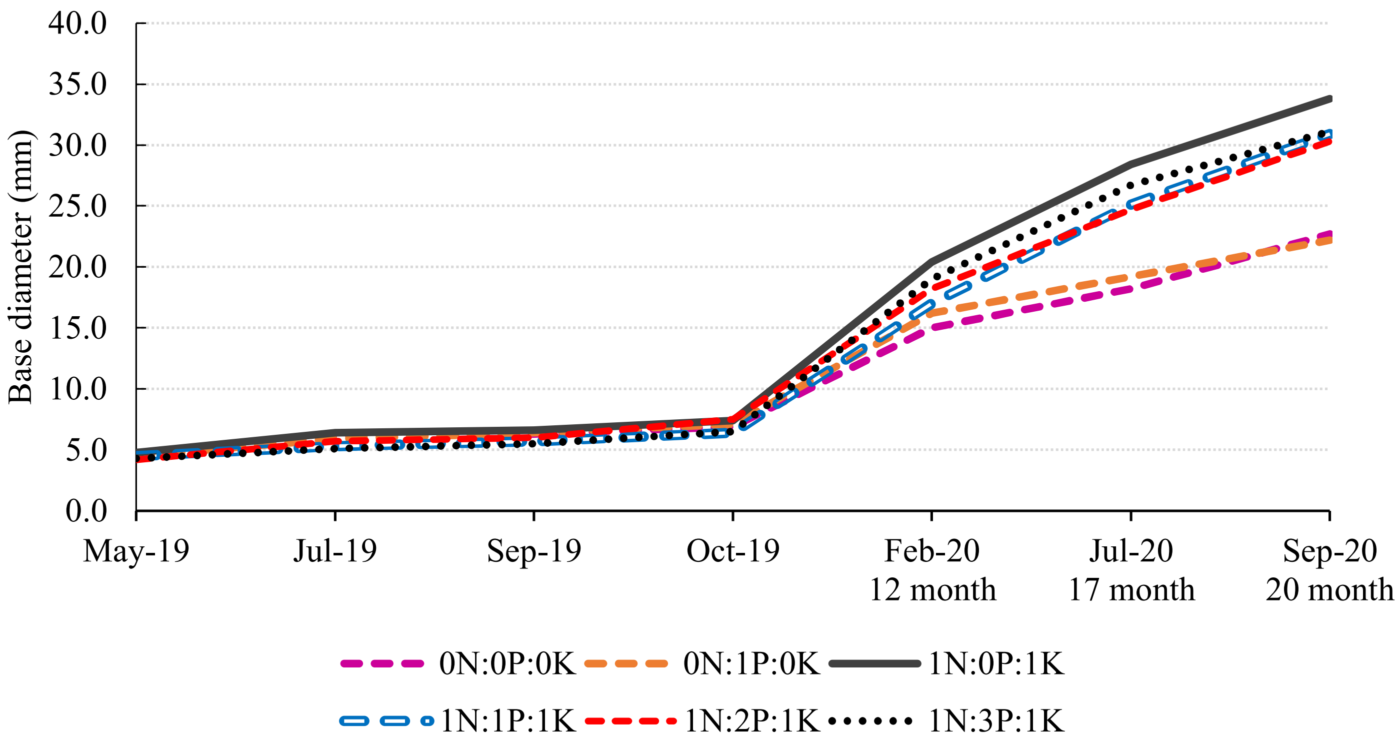
Base diameter (mm)
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
May-19
Jul-19
Sep-19
Oct-19
Feb-20
12 month
Jul-20
17 month
Sep-20
20 month
0N:0P:0K
0N:1P:0K
1N:0P:1K
1N:1P:1K
1N:2P:1K
1N:3P:1K

Table 1 – Different doses of Nitrogen (N), Phosphorus (P), and Potassium (K) fertilization used in *Eremanthus erythropappus* in Lavras, MG.

Treatment	**N (g)**	**P (g)**	**K (g)**
0N:0P:0K	0	0	0
0N:1P:0K	0	100	0
1N:0P:1K	80	0	80
1N:1P:1K	80	100	80
1N:2P:1K	80	200	80
1N:3P:1K	80	300	80

Table 2 - Summary of soil analysis of Red Latosol in Lavras, MG.

pH	**OM**	**P**	**K**	**Ca**	**Mg**	**SB**	**Al**	**H+Al**	**T**	**V**	**m**
	dag.kg^{-1}	.. mg.dm^{-3}...		.... mmol$_c$.dm^{-3}.......................						.... %	
5.4	1.35	1.22	37.02	1.36	0.30	1.75	0.1	2.27	4.02	43.65	5.41

OM: organic matter; SB: sum of bases; T: cation exchange capacity at pH 7.0; V: base saturation; m: aluminum saturation; P, K, Ca e Mg extracted by the ion exchange resin method.

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Table 3 - Summary of analysis of variance for height (H) and root collar diameter (RCD) of *E. erythropappus* seedlings over 20 months after planting, as a function of planting and topdressing fertilization in Lavras, MG.

Source of Variation	DF	Mean Square		
		12 months	17 months	20 months
			Height (cm)	
Block	3	515.745*	563.186*	725.532*
Treatment	5	268.376*	572.370*	581.232*
Residuals	15	82.274	199.848	188.118
Mean	-	109.2	158.6	161.8
CV (%)	-	8.3	8.9	8.5
			Base diameter (mm)	
Block	3	23.007*	2.107^{ns}	16.439*
Treatment	5	15.503*	67.014*	93.823*
Residuals	15	3.796	8.371	5.073
Mean	-	17.62	23.71	28.5
CV (%)	-	11.06	12.2	7.9

*: statistically significant at 7% error probability through F test; ns: non-statistically significant at 7% error probability through F test.

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Table 4 – Height (H) and base diameter (BD) mean of *Eremanthus erythropappus* seedlings over 20 months after planting with different fertilizations in Lavras-MG, Brazil.

Treatment	12 months	17 months	20 months
		Height (cm)	
0N:0P:0K	103.2 b	142.4 b	151.0 b
0N:1P:0K	100.2 b	146.8 b	146.1 b
1N:0P:1K	123.6 a	175.0 a	180.2 a
1N:1P:1K	107.5 b	163.0 a	164.7 a
1N:2P:1K	112.1 b	163.0 a	164.6 a
1N:3P:1K	108.4 b	161.2 a	164.3 a
		Base diameter (mm)	
0N:0P:0K	14.9 b	18.2 b	22.2 b
0N:1P:0K	16.2 b	19.2 b	22.7 b
1N:0P:1K	20.4 a	28.4 a	33.7 a
1N:1P:1K	17.0 b	25.0 a	30.9 a
1N:2P:1K	18.2 a	24.7 a	30.3 a
1N:3P:1K	19.0 a	26.7 a	31.1 a

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