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EVALUATION OF DIFFERENT COMBATING COMBINATIONS AGAINST LEAF-CUTTING ANTS IN *Eucalyptus urograndis* PLANTINGS

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Resumo

Avaliação de diferentes combinações de combate a formigas-cortadeiras em plantio de Eucalyptus urograndis. As formigas-cortadeiras, gêneros *Atta* e *Acromyrmex*, são uma das principais pragas dos cultivos florestais. Elas podem afetar a produtividade da floresta e aumentar a mortalidade dos plantios, sendo essencial seu combate. Dessa forma, o estudo teve como objetivo avaliar diferentes tratamentos de combate a formiga-cortadeira e seus resultados no inventário florestal de sobrevivência. Seis tratamentos foram avaliados, em uma área de aproximadamente 14 mil hectares de plantios de *Eucalyptus urograndis* (*Eucalyptus urophylla* S. T. Blake X *Eucalyptus grandis* W. Hill), sendo: 1) controle, 2) combate pré-corte, 3) combate pré-plantio, 4) dois ou mais combates pré-plantio, 5) combate pré-corte e combate pré-plantio e 6) combate pré-corte e dois ou mais combates pré-plantio. As variáveis analisadas foram: área plantada (ha), sobrevivência de plantio (%), mudas atacadas mortas (%), mudas atacadas vivas (%) e mudas atacadas totais (%). A comparação dos tratamentos foi realizada por meio da análise de variância multivariada e análise de discriminantes. Os tratamentos em que foi realizado o combate a formiga somente pré-corte ou combinado ao pré-plantio apresentaram os melhores desempenhos entre os tratamentos avaliados. O tratamento mais eficiente foi o que combateu as formigas no pré-corte com apenas uma repetição, o que resulta em redução de custos silviculturais.
Palavras-chave: manejo florestal; sobrevivência de plantio; silvicultura; MANOVA.

Abstract

Leaf-cutting ants, genera *Atta* and *Acromyrmex*, are one of the main pests in forestry crops. They can affect forest productivity and increase mortality rates in plantations, making their control essential. Thus, this study aimed to evaluate different treatments for combating leaf-cutting ants and their results on the forest inventory of survival. Six treatments were evaluated in an area of approximately 14.000 hectares of *Eucalyptus urograndis* (*Eucalyptus urophylla* S. T. Blake × *Eucalyptus grandis* W. Hill), namely: 1) control, 2) pre-harvest combat, 3) pre-planting combat, 4) two or more pre-planting combats, 5) pre-harvest and pre-planting combat, and 6) pre-harvest combat with two or more pre-planting combats. The analyzed variables were: planted area (ha), planting survival (%), dead attacked seedlings (%), live attacked seedlings (%), and total attacked seedlings (%). Treatment comparisons were conducted using multivariate analysis of variance and discriminant analysis. Treatments that involved combat against ants only before harvesting or combined with pre-planting showed the best performance among the evaluated treatments. The most efficient treatment was the one that combated the ants before harvesting with just one repetition, resulting in reduced silvicultural costs.
Keywords: forestry management; plantation survival; silviculture; MANOVA.

INTRODUCTION

Brazil is one of the most important forest-producing countries in the world. Currently, the country has 9.93 million hectares of planted forests, with 7.53 million hectares dedicated to eucalyptus cultivation (IBA, 2022). The natural conditions, combined with good management practices and research developments, result in productivities exceeding 38 m³/ha/year for this genus (IBA, 2022). One of the factors affecting forest productivity is mortality, which can be related to competition within the forest, as well as wind, fire, or pest attacks (DE MIRANDA *et al.*, 2017; AMARAL *et al.*, 2019; SCHERF *et al.*, 2022).

One of the main pests of eucalyptus plantations is leaf-cutting ants, from the genera *Atta* and *Acromyrmex*, commonly known as saúvas and quenquéns, respectively. The attack of leaf-cutting ants affects approximately 15% of plantation productivity (ZANETTI, 2020). The estimated consumption of an adult colony of *Atta* ants is one ton of plant material per year (BARBOSA *et al.*, 2021).

The main method of combating these ants is chemical control using baits containing the active ingredients sulfluramid or fipronil (OLIVEIRA, 2011). The timing of combat may vary depending on the genus present in the

area: saúvas cause damage and should be controlled throughout the forest cycle, while quenquéns tend to cause damage in the early stages of the forest (BARBOSA *et al.*, 2021).

According to Della Lucia and Amaral (2020), about 30% of the cost of managing forest plantations is related to the control and detection of leaf-cutting ants. Zanetti (2017) emphasizes the importance of conducting more studies on leaf-cutting ants to achieve efficient management for controlling this pest.

In this sense, the timing of the application of formicidal baits can be a determining factor in the effectiveness of combating the ants. In areas with forest plantations, the forester can conduct the application before harvesting the forest, even when the anthills are intact, or before planting. Zanetti *et al.* (2014) and Boaretto and Forti (1997) highlight that the most critical phases for combating ants in forest plantations are during the pre-harvest and pre-planting stages.

Several studies present research on combating ants, such as Cantarelli *et al.* (2006), Vitorino *et al.* (2014), Meneghetti *et al.* (2015), and Vinha *et al.* (2020); however, there is a need to evaluate variations in the timing of pre-harvest and pre-planting combat, as well as the number of combats conducted.

Thus, the objective of this study was to evaluate different treatments for combating leaf-cutting ants, varying the timing and number of combats performed, between pre-harvest and pre-planting, in relation to five variables: planted area, planting survival, and the percentage of seedlings attacked by ants, dead, alive, and total.

MATERIAL AND METHODS

Experiment Characterization

The experiment was conducted in the Campos Gerais region of the state of Paraná (BR), across 14.448 hectares (ha) of *Eucalyptus urograndis* (*Eucalyptus urophylla* S. T. Blake × *Eucalyptus grandis* W. Hill) plantations from the years 2021. 2022. and 2023. The study encompasses areas of reform, meaning areas where the previous land use was planted forest.

The study area was subjected to six different treatments for combating ants, varying the number and timing of combats. The methods used were:

- Pre-harvest: conducted before the harvest of the forest, varying from 15 to 180 days prior to clear-cutting;
- Pre-planting: can be performed either before or after soil preparation: if before, respecting a period of 30 days post-harvest; if after, respecting 30 days from preparation.

Thus, the treatments varied in:

- T1: no ant control, evaluated in 1.409 ha;
- T2: pre-harvest ant control, evaluated in 1.280 ha;
- T3: one pre-planting ant control, evaluated in 3.889 ha;
- T4: two or more pre-planting ant controls, evaluated in 1.401 ha;
- T5: pre-harvest ant control and one pre-planting control, evaluated in 4.964 ha;
- T6: pre-harvest ant control and two or more pre-planting controls, evaluated in 1.505 ha.

All combats were carried out using ant bait, with an active ingredient of sulfluramid at a concentration of 0.2%. The application method was systematic, applying a dose (10g) for every 25 m², and localized if the anthill was identified at the time of systematic application.

Five variables were used in the analysis: planted area in hectares (X1), percentage of planting survival (X2), percentage of live seedlings attacked by ants (X3), percentage of dead seedlings attacked by ants (X4), and total percentage of seedlings attacked by ants (X5). Field data collection (X2. X3. X4. and X5) was conducted through the survival forest inventory (IFS), 15 days after planting, which assesses the survival and quality of the seedlings by walking along the tenth planting row, aiming to sample approximately 10% of the planted area.

Analysis of Experimental Data

Once the approach of homogeneous variance-covariance matrices was identified, multivariate analysis was initiated through multivariate analysis of variance (MANOVA) of the variables: area, survival, dead attacked seedlings, live attacked seedlings, and total attacked seedlings, by treatment, with the objective of testing the significance of the mean differences between the treatments. The tests performed were: Pillai's trace, Wilks' lambda, Hotelling's trace, and Roy's maximum root, indicating differences between the groups if the significance value (P) was less than 0.05.

After rejecting the multivariate null hypothesis, discriminant analysis was conducted with the aim of classifying the treatments and identifying the most important variables in the analysis. Due to the units of measurement of the variables, standardized canonical discriminant functions were established.

All tests and analyses were conducted with the assistance of IBM SPSS Statistics software, evaluation version.

RESULTS

The treatments were subjected to the four tests in the MANOVA, which indicated statistical differences between the treatments (Table 1), with values less than 0.01 for Pillai's Trace, Wilks' Lambda, and Hotelling's Trace, and less than 0.007 for Roy's Maximum Root.

Table 1. Multivariate variance analysis results for the evaluated treatments.
Tabela 1. Resultados da análise de variância multivariada para os tratamentos avaliados.

Source of Variation	Test	Value	F	P-value
Treatment	Pillai's Trace	0.039	2.519	<0.010
	Wilks' Lambda	0.962	2.518	<0.010
	Hotelling's Trace	0.039	2.517	<0.010
	Roy's Maximum Root	0.028	3.541	<0.007

Quatro funções discriminantes foram geradas, descrevendo 100% da variância, sendo que as duas primeiras explicaram 93,7% (72,9% e 20,8%, respectivamente) e com correlações canônicas entre variáveis e função de 0,25 e 0,14, respectivamente (Tabela 2).

Table 2. Results of the percentage of total variance explained by the obtained discriminant functions, related to the found eigenvalues and canonical correlation coefficients..
Tabela 2. Resultados da porcentagem da variância total explicada pelas funções discriminantes obtidas, relativas aos autovalores encontrados e coeficientes de correlação canônica.

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	0.067	72.9	72.9	0.250
2	0.019	20.8	93.7	0.137
3	0.005	5.0	98.7	0.067
4	0.001	1.3	100.0	0.035

In the canonical correlation, the planting survival variable (X2) had the greatest weight in function 1, while the planted area variable (X1) was for function 2. The variable for live attacked seedlings (X3) was in function 3, and the variables for dead attacked seedlings (X4) and total attacked seedlings (X5) were in function 4.

Table 3. Results of the canonical correlations between the evaluated original variables and the obtained discriminant functions.
Tabela 3. Resultados das correlações canônicas entre as variáveis originais avaliadas e as funções discriminantes obtidas.

Variable	Function			
	1	2	3	4
X1	0,660	-0,668*	-0,054	0,338
X2	0,744*	0,293	0,274	-0,534
X3	-0,382	-0,413	0,816*	-0,131
X4	-0,276	0,204	0,261	0,903*
X5	-0,403	-0,012	0,584	0,705*

The highest survival rate was in T5, at 96.15%, while the lowest was in T1, at 90.83%. The other treatments varied between 93.57% and 94.83% average survival (Table 4). Regarding seedlings attacked by ants, treatments T1, T3, and T4 showed the highest rates, with T1 and T3 having values exceeding 1.07% of live attacked seedlings, T1 and T4 having values greater than 2.04% of dead seedlings, and 2.8% total attacked seedlings, with values greater than 2.04% of dead seedlings. The lowest ant attack rates were in treatments T2 and T6, at 1.61% and 1.73% of total attacked seedlings, respectively.

Table 4. Results obtained for the means of the variables planted area, survival, live seedlings, dead seedlings, and total seedlings for each treatment.
Tabela 4. Resultados obtidos para as médias das variáveis área plantada, sobrevivência, mudas vivas, mudas mortas e mudas totais para cada tratamento.

Treatment	Planted area (ha)	Survival	Live Seedling	Dead seedlings	Total seedlings
1	6,35	90,83%	1,57%	2,04%	3,61%
2	13,77	94,83%	0,56%	1,05%	1,61%
3	8,26	93,57%	1,07%	1,84%	2,91%
4	6,02	93,77%	0,66%	2,14%	2,80%
5	10,80	96,15%	0,75%	1,23%	1,98%
6	8,60	94,47%	0,59%	1,15%	1,73%

When correlating planted area (ha) with total seedlings attacked by leaf-cutting ants, there is a noticeable trend of lower attack rates in areas with larger average planted areas (ha) (Figure 1).

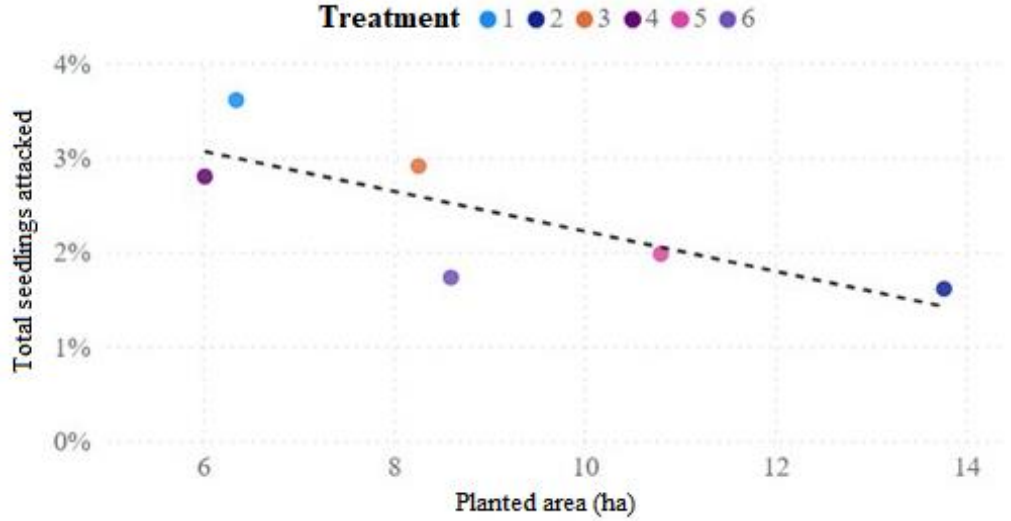

Figure 1. Percentage of total seedlings attacked by ants by the average planted area of treatments T1 to T6 and their trend.
Figura 1. Percentual de mudas atacadas por formigas total pela área média plantada dos tratamentos T1 a T6 e sua tendência.

DISCUSSION

Despite the restrictions on formicidal baits containing sulfluramid from forest certifications (VINHA *et al.*, 2020), this chemical control method remains the most effective and widely used in the forestry sector, as noted by Vitorino (2014), Zanetti *et al.* (2014), Vinha *et al.* (2020), and Della Lucia and Amaral (2020).

This study highlights the need for controlling leaf-cutting ants before planting, as treatments in which combats were carried out resulted in higher survival rates and lower ant attack rates. This result was expected, as this is the critical phase for combating ants in plantations, as stated by Zanetti *et al.* (2014) and Boaretto and Forti (1997).

Considering the values obtained for the variables in each treatment, it was observed that treatment T2, which involved only pre-harvest ant control, presented the second highest percentage of planting survival and the lowest ant attack rates, making it the most recommended combat method, as it only requires one application. According to Cantarelli *et al.* (2006), reducing the number of combats decreases costs and minimizes environmental contamination and risks to workers.

The recommendation for treatment T2 can be supported by analyzing that the other treatments with higher survival rates and lower ant attacks, T5 and T6, also include pre-harvest control. As noted by Cavalcanti *et al.* (2019), the entry of heavy machinery (for harvesting and soil preparation) or cattle trampling disrupts the anthills, temporarily halting the activity within the colony and influencing the uptake of baits. Therefore, pre-harvest control targets fully active anthills.

The trend of lower ant attacks as the planted area increases can be explained by the greater distances within the plot and, consequently, the greater difficulty for ants to occupy the total area. Zanetti *et al.* (2000) found that plots adjacent to fragments of native forests had 13.04% higher densities of saúva ants, while plots farther away from these fragments exhibited lower saúva densities.

CONCLUSION

- The evaluated ant control treatments indicate differences among them.
- Pre-harvest control is the most effective treatment, as it involves only one application of the control operation, resulting in lower costs as well.
- Treatments T2, T5, and T6 show the highest planting survival rates and the lowest ant attack rates. However, these three treatments have in common the pre-harvest control, which reinforces the importance of this type of control for managing leaf-cutting ants in eucalyptus plantations.

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