Soil chemical attributes in native and exotic forest cover in source of Batatais State Forest, São Paulo, Brazil

Atributos químicos do solo em coberturas florestais nativas e exóticas no manancial da Floresta Estadual de Batatais, São Paulo, Brasil

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ABSTRACT
The development of native forest species planted 20 years ago in the Batatais State Forest was evaluated by collecting soil for analysis of sample homogeneity and comparison with other uses/occupation. Along the canopy projection of eight native species (27 individuals), of progenies of *Eucalyptus pellita* (25), *E. tereticornis* (30), of the commercial plantation of *Pinus caribaea hondurensis* (52) and *P. c. bahamensis* (69) composite soil samples were collected at a depth of 0-0.20 m. The multivariate analysis of the Afforestation soil attributes was not significant for the studied native species, indicating the soil homogeneity in each treatment and that any alterations found in the native species are due to genetic factors, but not related to the studied soil chemical attributes. On the other hand, the analyzes of the different uses/occupations were highly significant, showing that there is a difference in the attributes of the soil in relation to the different uses/occupations. *Eucalyptus* has a higher base content than *Pinus* and Afforestation, in areas with lower potential acidity and greater cation exchange capacity (CEC), leaving the area with Afforestation higher potential acidity and lower CEC.

Keywords: riparian forest, degraded area recovery, multivariate analysis.

RESUMO
Este trabalho tem por objetivo analisar a homogeneidade das amostras de solo das árvores nativas plantadas há 20 anos na Floresta Estadual de Batatais em comparação com outros usos/ocupação. Ao longo da projeção da copa de oito espécies nativas foram coletadas amostras compostas de solo na profundidade 0-0,20 m, que foram avaliadas junto com o solo de outros estudos com árvores de progênies de *Eucalyptus pellita*, de E. *tereticornis* e do plantio comercial de *Pinus caribaea hondurensis* e P. c. *bahamensis*. A análise multivariada dos atributos do solo das espécies nativas restou não significativa, indicando a homogeneidade do solo na área de estudo, restando a expressão genética das espécies para outras variáveis *dendrométricas* e de qualidade da madeira a serem estudadas. Por outro lado, a análise multivariada das espécies nativas com as de *Eucalyptus* e *Pinus* resultaram altamente significativas, mostrando que existe diferença dos atributos do solo em relação aos diferentes usos/ocupações. Os *Eucalyptus* apresentam maior teor de bases que o *Pinus* e o Florestamento, em áreas com menor acidez potencial e maior capacidade de troca de cátions (CTC), restando à área com Florestamento maior acidez potencial e menor CTC.

Palavras-chave: mata ciliar, recuperação de área degradada, análise multivariada.

1 INTRODUCTION

Economic value of forests, growth ecology and management are current innovations in native tree plantations. The 2030 Agenda of Sustainable Development Goals reinforces the Convention on Biological Diversity (COP15) held in China in October 2020, highlighting the value of restoring and conserving biodiversity by 2050 and further encouraging the maintenance of ecosystem services in favor of a sustainable development. Thus, restoration of ecosystems and recomposition of vegetation must be promoted in line with strategies addressing the compatibility of agricultural / forestry production, territorial development and biodiversity (Carta de São Paulo 2020).

Silvicultural systems for production of solid wood based on the intercropping of several species are rare owing to the complexity of managing a system where species have different growth rates, different cutting cycles and different requirements for light and space for growth. However, polycyclic systems can guarantee the maintenance of stands without clear-cutting. This is achievable because high species diversity can guarantee successive harvests in addition to returning functional connectivity. Such system is favored for the silviculture of native species, mainly in the Degraded Legal Reserve areas of the Atlantic Forest (Rolim and Piotto 2018). However, poor understanding of silvicultural characteristics of most tropical species, coupled with the interaction among different ecological conditions, has caused some restoration programs to fail.

In riparian forests and recovery areas of degraded forests, different silvicultural methods and forest species are used and selected according to site characteristics. Since 1978, research conducted by the Environmental Research Institute (formerly Forest Institute) has led to the introduction of the Forest Genetic Improvement Program for *Pinus* spp., *Eucalyptus* spp., and Brazilian native species. This program aims to select progenies adapted to low soil fertility conditions and evaluate / explore the variability of existing material for continuous gains (Gurgel Garrido *et al*. 1997). *Eucalyptus pellita* and *E. tereticornis* progenies, as used in this study, were planted in the Batatais Forest, São Paulo State, comprising this ex situ genetic conservation bank.

The multivariate analysis performed by Araújo et al. (2021) indicated the Helenvale procedence for vegetative reproduction (cloning) of the material that makes up the Batatais Forest collection, based on the wood quality variables studied. They also concluded that the fiber length (Fwt) in the intermediate position (I) was influenced by groups of soil variables with lower values of Ca, Mg and pH and lower values of P, organic matter and cation exchange capacity.

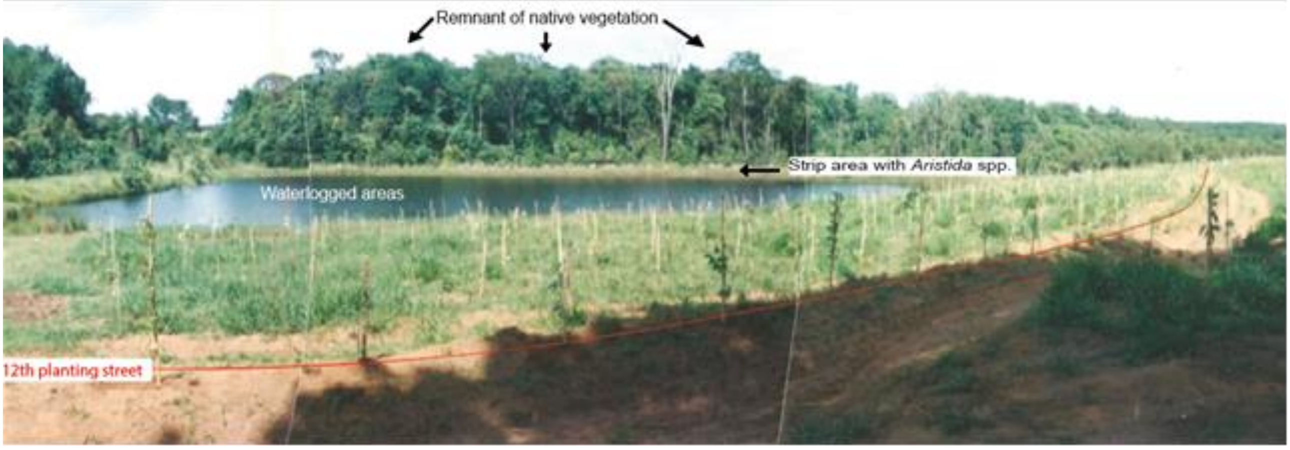
Different chemical attributes of soil behave in very different ways along cultivated areas, owing, among other factors, to alterations provoked by agricultural management (Silva *et al*. 2010). Therefore, the effect of management systems and land use must be considered in order to completely understand the variation in soil quality and its impact on tree growth and then undertake corrective action through appropriate conservation practices (Rahmanipour *et al*. 2014; Guimarães *et al*. 2013).

Thus, in our study with afforestation of 10 native species compared with two *Eucalyptus species* (*E. pellita* and *E. tereticornis*) and two tropical *Pinus* species (*Pinus caribaea* var. *hondurensis* and *Pinus caribaea* var. *bahamensis*). We aimed to analyze soil homogeneity samples of native trees compared to these other uses/occupations. We hypothesize that these attributes are uniform across the terrain. Thus, other variables (dendrometric or wood quality) that have significant prominence for these uses/occupations studied can also be indicated for asexual reproduction of this collection.

2 MATERIALS AND METHODS

The municipality of Batatais is located between two Water Resources Management Units (UGRHI), Sapucaí-Mirim/Grande Hydrographic Basin (UGRHI 8) and Pardo Basin (UGRHI 4), in the northeastern part of the State of São Paulo. The climate is classified by the Köppen System as Cwa, indicating that the average temperature in the warm months is above 22°C and in the cold months below 18°C. Frosts are rare or infrequent, and water deficit is small or nil. Annual rainfall varies between 1100 and 1700 mm $year^{-1}$, with July being the month with the lowest rainfall and January the highest (Zanata *et al*. 2015). The São Bento Group, with sedimentary rocks from Piramboia and Botucatu formations, which form the Guarani Aquifer, the basaltic igneous rocks from the Serra Geral Formation, and the sedimentary deposit from the Itaqueri Formation, makes up the geological stratigraphy of the study area (Zanata 2013). The subdivision adopted in the Geomorphological State of São Paulo Map shows that this region belongs to the Geomorphological Province of the Basaltic Cuestas (Zanata and Pissarra 2012). The Brazilian Soil Classification System (EMBRAPA 2006; Rossi 2017) indicates the area as having medium textured soil, such as Dystroferric Red Latosol, Dystrophic Red Yellow Latosol, and Gleissolos in alluvial floodplains. The native vegetation cover is composed of an ecological tension area between the Seasonal Semideciduous Forest and the Cerrado physiognomies (IBGE 2012). The study was carried out during 1999 and 2000 in a forestation of 20,000 native trees at the main source of the Estiva Stream, the main compartment of the urban water supply in Batatais (Figure 1).

Figure 1. View of first contour line where the 12th planting street was fitted. In the background, a remnant of native vegetation in an advanced stage of natural regeneration covers the waterlogged areas of the spring and strip area with grass (*Aristida* spp.) of its permanent preservation area (APP).



Pasture land preceded land preparation with the natural regeneration of herbaceous plants or isolated shrubs and the presence of grass (*Aristida* spp.) in humid places. Afforestation began in November 1999 with the first mowing, leveling of terraces for soil conservation, and designing of planting lines. The opening of pits, distributing of inputs, staking, crowning and clearing were carried out in December 1999. The first planting stage was carried out in January and February 2000 (Figure 1). The planting streets follow the lay of the land, along four level curves (terraces) installed, respecting the spacing of three meters between streets and two meters between plants on the street. The second planting stage was carried out in January and February of 2001 and then replanting of the total area in December 2001

The arrangement of species in the planting area considered the growth and development characteristics of each one (pioneer, secondary or climax), working with just over eighty (80) tree species in the first year, seventy (70) species in the second year of planting and the same number of species in the replanting, which resulted in more than a hundred species of native and exotic trees planted in that location. Figure 2 indicates the change in the landscape through the satellite images of the Google Earth system, showing ground cover and closing of the forest produced, forming a buffer zone of original vegetation.

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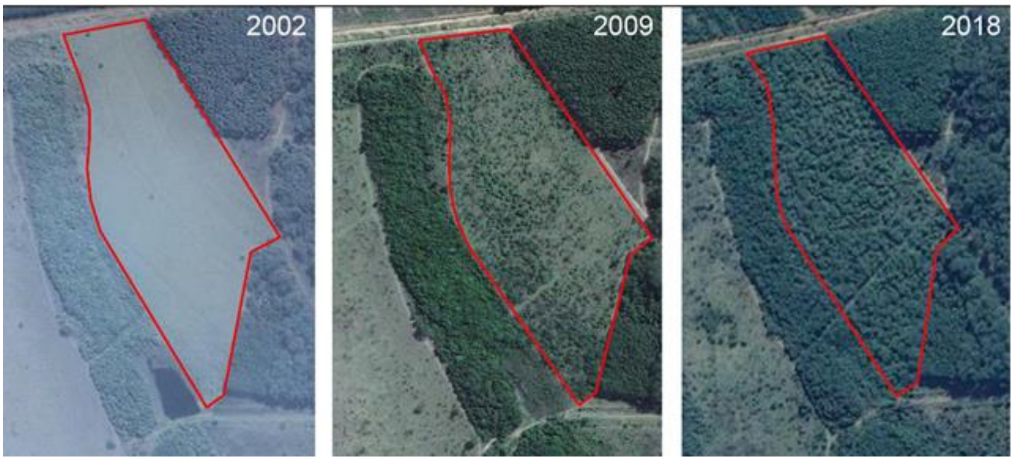
Figure 2. Planting development in 2002, 2009 and 2018, respectively. Source: Google Earth.



In this study with native species, the early choice of tree species aimed to minimize the effect on experimental conduct by avoiding tendencies and biases. The local effect was mitigated by choosing three individuals of each species. The first forays into the field were carried out in order to verify the then current situation of streets and plants, according to planting and replanting sketches. The plantation had a rich natural regeneration of climbing plants, shrubs, trees and several members of fauna and flora that had formed over the course of 20 years on the path shown in figure 3.

Along the canopy projection of 27 trees of 10 native species (Table 1), soil samples were collected at a depth of 0-0.20 m. Air-dried soil samples were analyzed for phosphorus (P); organic matter (O.M.), pH in CaCl2, potassium (K), calcium (Ca), magnesium (Mg), potential acidity (H++Al+3), sum of bases (SB), cation exchange capacity (CEC) and base saturation (V%). Soil analysis was carried out according to the procedures described by van Raij et al. (1996).

Figure 3. View from end of track formed by first contour line. Highlight of *Anadenanthera macrocarpa* tree among a high diversity of species where once there was a pasture of *Urochloa* spp.

Table 1. Popular and scientific names of native Brazilian species

Popular names	Scientific names	Abbreviation
Ingá	*Inga uruguensis* Hooker at Arnott	*I. uruguensis*
Pau jacaré	*Piptadenia gonoacantha* (Marth) Macbr.	*P. gonoacantha*
Embaúba	*Cecropia pachystachya* Trec.	*C. pachystachya*
Araribá	*Centrolobium tomentosum* Guillemin ex Benth	*C. tomentosum*
Amarelinho	*Terminalia brasiliensis* Camb.	*T. brasiliensis*
Peito de pombo	*Tapirira guianensis* Aubl.	*T. guianensis*
Ipê amarelo	*Handroanthus chrysotrichus* (Mart. ex DC.) Mattos	*H. chrysotrichus*
Araçá do campo	*Psidium cattleianum* Sabine	*P. cattleianum*
Óleo de copaíba	*Copaifera langsdorffii* Desf.	*C. langsdorffii*
Pitanga	*Eugenia uniflora* L.	*E. uniflora*

The *E. pellita* provenance and progeny test was installed in Batatais State Forest in 1986 with geographic coordinates of 20º53’28"S latitude and 47º35'06”W longitude and average altitude of 862 meters. The 25 progenies tested originated from open pollination of selected parent trees in two natural populations in Australia: Helenvale (nine progenies) and Coen (16 progenies). The experimental design used for planting was that of random blocks. The plots consisted of 25 plants, one from each progeny, with a spacing of 4 m x 4 m, with 100 replications. From the dendrometric data obtained in 2009 (Zanata *et al*. 2010) and from field observations, 25 individuals were chosen, one from each progeny. Therefore, we divided the planting area into 25 samples, consisting of 4 plots of the experimental design, leaving 4 plants to be evaluated by randomly selected progeny.

Similarly, from dendrometric data obtained in 2011 (Macedo *et al*. 2013) and field observation, 30 progenies were randomly chosen from *E. tereticornis* provenance and progeny test, also installed in February 1986 in Batatais State Forest, with plots of six plants arranged in a row and 10 repetitions (blocks) in a 3.0 x 2.0 m spacing with double borders. The seeds of parent trees came from three natural populations in Australia, incuding Helenvale (20 progenies), Ravenshoe (19 progenies) and Mount Garnet (13 progenies).

Finally, the commercial planting of two varieties of *Pinus* was carried out in 2011 in Batatais State Forest (plots 21 and 22) with a spacing of 3.0 m x 3.5 m. Here, we added scientific value with a geostatistical analysis of soil samples (Ruiz 2016) collected at the crossing points of a mesh with regular intervals of 36 m, totaling an area of 16 ha with *Pinus* at a depth of 0-0.20 m. The area was staked with a total station and points georeferenced with a GPS navigation receiver with control points outside of the area to avoid interference with the registration of points.

Multivariate analysis is more suitable for evaluating multiple variables, reducing the number of variables and improving the interpretation of results (Silva *et al*. 2020; Oliveira Júnior *et al*. 2019; Zanata *et al*. 2015; Mota *et al*. 2014; Zanata 2013; Souza *et al*. 2012). From factors extracted by the principal components method, the first factor is a linear combination of original variables, aggregatng as much variation as possible in the samples. The second factor is a second linear function of original variables. Here, the variables are standardized (normal distribution, mean = 0, variance = 1), and the coefficients of linear functions define the factors used and interpretation of their meaning. The factors were tested by the general linear model (GLM) and by Fisher's exact test of means with a statistical significance of 5% ($p < 0.05$). Multivariate analyses were processed in the Statistica program from Hill and Lewicki (Statsoft® 2007). Univariate analyses were performed using the same software according to Fisher's exact test at 5%.

3 RESULTS AND DISCUSSION

The composition of completely randomized design requires at least seven species or main treatments with three replications. Accordingly, *I. uruguensis*, *P. gonoacantha*, *C. pachystachya*, *C. tomentosum*, *T. brasiliensis*, *T. guianensis*, *H. chrysotrichus*, *P. cattleianum*, *C. langsdorffii*, and *E. uniflora* were chosen. The identification of collected plants was carried out based on planting sketches, on-site observation and available literature (Lorenzi 2000; Durigan *et al*. 2004; Carvalho 1994; Campos Filho and Sartorelli 2015; Voluntariado 2021).

Table 2 presents reference values for the evaluation of soil attributes. Table 3 presents values obtained in the soil analysis.

Table 2. Reference values for some soil chemical characteristics

Interpretation	P resin				K^+	Ca^{2+}	Mg^{2+}	V	Acidity
	annuals	forestry	perennials	vegetables					(pH)
	------------------- mg dm^{-3} -------------------				--------- $mmol_c\ dm^{-3}$ --------			%	
Very low	0-6	0-2	0-5	0-10	0-0.7			0-25	>6.0
Low	7-15	3-5	6-12	11-25	0.8-1.5	0-3	0-4	26-50	5.6-6.0
Average	16-40	6-8	13-30	26-60	1.6-3.0	4-7	5-8	51-70	5.1-5.5
High	41-80	9-16	31-60	61-120	3.1-6.0	>7	>8	71-90	4.4-5.0
Very high	>80	>16	>60	>120	>6.0			>90	up to 4.3

Source: Soil and Plant Analysis Laboratory of the Department of Soils and Fertilizers, Faculty of Agrarian and Veterinary Sciences (FCAV), São Paulo State University "Júlio de Mesquita Filho" – Campus de Jaboticabal, SP, Brazil

Table 3. Data from analysis of soil attributes of Brazilian native species planting, Batatais, SP, Brazil

Species	P (mg dm^{-3})	O.M. (g dm^{-3})	pH ($CaCl_2$)	K (mmol$_c$ dm^{-3})	Ca (mmol$_c$ dm^{-3})	Mg (mmol$_c$ dm^{-3})	H+Al (mmol$_c$ dm^{-3})	SB (mmol$_c$ dm^{-3})	CEC (mmol$_c$ dm^{-3})	V (%)
I. uruguensis	5.00	19.53	3.8	0.6	1.0	1.0	55.0	2.6	57.6	4.51
I. uruguensis	5.19	20.78	3.7	0.5	3.0	1.0	64.0	4.5	68.5	6.57
I. uruguensis	5.00	17.28	3.8	0.6	1.0	1.0	52.0	2.6	54.6	4.76
P. gonoacantha	6.13	20.78	3.8	0.6	2.0	1.0	52.0	3.6	55.6	6.47
P. gonoacantha	5.38	20.28	3.8	0.6	1.0	1.0	58.0	2.6	60.6	4.29
P. gonoacantha	5.75	16.28	3.7	0.5	5.0	1.0	55.0	6.5	61.5	10.57
C. pachystachya	4.62	15.28	3.7	0.4	3.0	1.0	58.0	4.4	62.4	7.05
C. pachystachya	8.40	22.03	3.7	0.8	1.0	2.0	72.0	3.8	75.8	5.01
C. pachystachya	7.08	15.53	3.8	0.7	2.0	1.0	52.0	3.7	55.7	6.64
C. tomentosum	4.81	16.78	3.6	0.6	2.0	1.0	52.0	3.6	55.6	6.47
C. tomentosum	5.94	16.53	3.9	0.5	9.0	1.0	52.0	10.5	62.5	16.80
C. tomentosum	3.87	17.28	3.8	0.5	1.0	1.0	47.0	2.5	49.5	5.05
T. brasiliensis	5.19	16.78	3.8	0.6	2.0	1.0	50.0	3.6	53.6	6.72
T. brasiliensis	5.75	21.53	3.9	0.7	5.0	2.0	52.0	7.7	59.7	12.90
T. brasiliensis	4.62	21.53	3.8	0.9	2.0	1.0	58.0	3.9	61.9	6.30
T. guianensis	8.02	19.53	3.8	0.8	7.0	1.0	61.0	8.8	69.8	12.61
T. guianensis	6.32	21.78	3.8	0.7	4.0	1.0	58.0	5.7	63.7	8.95
H. chrysotrichus	5.94	18.28	3.8	0.6	2.0	1.0	52.0	3.6	55.6	6.47
P. cattleianum	7.26	20.03	3.6	0.6	2.0	1.0	64.0	3.6	67.6	5.33
P. cattleianum	6.13	17.28	3.8	0.7	2.0	1.0	50.0	3.7	53.7	6.89
P. cattleianum	5.19	17.28	3.8	0.5	2.0	1.0	50.0	3.5	53.5	6.54
C. langsdorffii	4.43	22.28	3.8	0.4	2.0	1.0	55.0	3.4	58.4	5.82
C. langsdorffii	4.25	16.78	3.8	0.5	2.0	1.0	45.0	3.5	48.5	7.22
C. langsdorffii	5.57	17.28	3.7	0.6	3.0	1.0	58.0	4.6	62.6	7.35
E. uniflora	6.70	17.28	3.8	0.5	5.0	1.0	52.0	6.5	58.5	11.11
E. uniflora	5.57	19.78	3.9	1.0	2.0	1.0	58.0	4.0	62.0	6.45
E. uniflora	4.43	20.53	3.7	0.7	3.0	1.0	55.0	4.7	59.7	7.87

According to Lopes and Guidolin (1989), soil interpretation analysis shows that the experimental area has very high pH (up to 4.3) and very low base saturation (V%) (up to 25%), characterizing a region with high soil acidity and very low availability of cations for exchange. The average value of 18.75 g.dm^{-3} (1.87%) of organic matter (O.M.) in the soil does not reach the minimum level of 50 g.dm^{-3} or 5% of O.M. to be considered a sustainable soil, demonstrating critical conditions for development of these plants. The average contents of P, Ca and Mg are considered low for the production of forest species. The potential acidity (H^{+}+Al^{+3}) of 55.1 mmol$_{c}$. dm^{-3}, also known as exchangeable Al or harmful acidity, has a negative effect on the normal development of a large number of cultures.

The multivariate analysis of afforestation soil attributes remained non-significant for treatments, indicating that any statistical significance obtained by native arboreal plants is genetic or environmental and not from the soil. We then proceeded to conduct multivariate analysis of the afforestation soil attributes, along with the other covers evaluated in recent years, with two species of *Eucalyptus* (*E. pellita* and *E. tereticornis*) and two species of tropical *Pinus* (*P. hondurensis* and *P. bahamensis*). Factor analysis (Table 4) shows that that the first two factors represent 81.69% of the variability contained in the original variables. The largest possible variation in the sample is represented by first factor (F1=57.56%) with direct correlation among variables pH, K, Ca, Mg, SB and V. The second largest variation is represented by the second factor (F2= 24.13%) with a direct correlation among variables H^{+}+Al^{+3} and CEC.

Table 4. Eigenvalues of F1 and F2 factors for soil attributes, Batatais, SP, Brazil. Total observations = 203

Variables	F1	F2
P (mg.dm^{-3})	-0.09	0.61
O.M. (g.dm^{-3})	0.42	0.70
pH CaCl^{2}	**0.84**	-0.42
K (mmol$_{c}$.dm^{-3})	**0.76**	-0.22
Ca (mmol$_{c}$.dm^{-3})	**0.94**	0.06
Mg (mmol$_{c}$.dm^{-3})	**0.96**	-0.09
H^{+}+Al^{+3} (mmol$_{c}$.dm^{-3})	-0.46	**0.85**
SB (mmol$_{c}$.dm^{-3})	**0.98**	-0.01
CEC (mmol$_{c}$.dm^{-3})	-0.11	**0.95**
V (%)	**0.97**	-0.20

The two-dimensional plane of factors F1 and F2 (Figure 4A) indicates the groups formed by variables that compose the factors, considering the soil cover as main treatments. The correlation between variables of factors (F1 and F2) are soil attributes that are correlated with each other. The low pH values of soil are a function of amount of Ca and Mg, which, when added to K, results in the sum of bases (SB) and, consequently, base saturation (V%), showing that one value depends on another. The correlation indicated by F2 factor complements the process contained in F1, since the low availability of bases is related to the low pH value and high buffering power of the soil, owing to the higher potential exchangeable acidity ($H^{+}+Al^{+3}$) and, consequently, lower CEC. The mathematical and computational models studied by Lima et al. (2017) showed that hydrogen potential (pH), potential acidity ($H^{+}+Al^{+3}$) and Mg, P, K, and Al contents were all crucial characteristics impacting *Eucalyptus urograndis* growth.

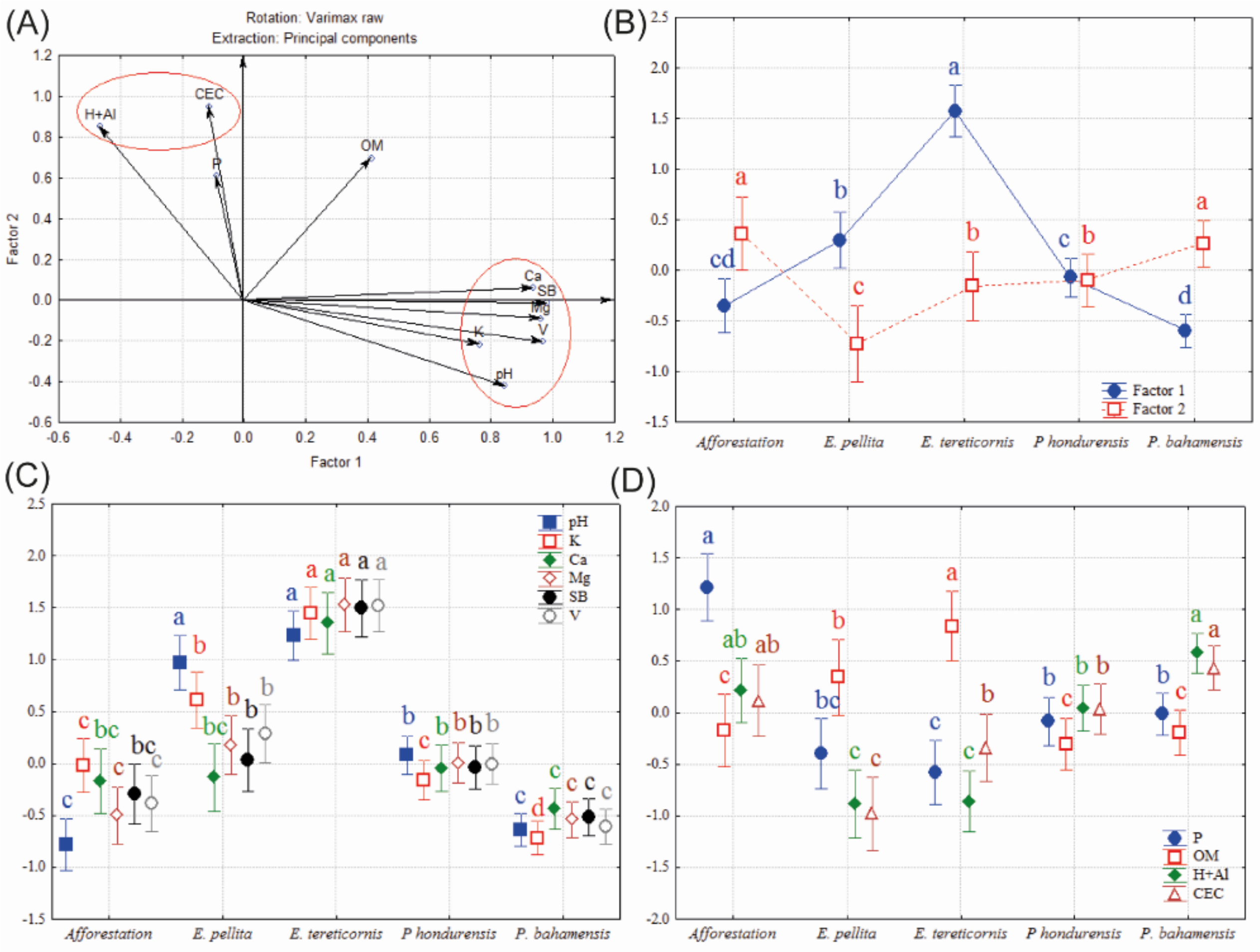
The analysis of variance (ANOVA) for F1 and F2, considering soil cover (reforestation, *Eucalyptus* and *Pinus*), indicates a highly significant effect on both factors. Specifically, a significant difference was found between soil coverages for variables grouped in F1 (pH, K, Ca, Mg, SB and V) and F2 ($H^{+}+Al^{+3}$ and CEC). The graph of Fisher's exact test ($p<0.05$) for factors F1 and F2 (Figure 4B) shows the difference between the coverages for both factors.

The values obtained for soil attributes in five land uses/occupations show that *Eucalyptus* trees have a higher base content than either Forestry or *Pinus* in an area with lower soil acidity. In factor F2, the opposite occurs such that *Eucalyptus* trees have less potential acidity and greater cation exchange capacity, while Forestry stands out for greater potential acidity and lower cation exchange capacity.

The univariate analysis (Figures 4C and 4D) with means comparison by Fisher's test at 5% ($p<0.05$) reveals in the ANOVA graphs the different behavior of soil cover as a function of the variables grouped in factors F1 and F2. The univariate analysis of soil cover as a function of each soil chemical variable grouped in F1 shows a significant difference for *E. tereticornis* in relation to the other soil covers. In general, the stand planted with *P. bahamensis* has behavior opposite from that of *E. tereticornis*.

The univariate analysis of variables grouped by F2 factor (Figure 4D) shows that afforestation stands out for lowest values of organic matter, possibly owing to the history of previous coverage with *Aristida* spp. pasture. Afforestation presents a significant difference in relation to the other coverages in terms of phosphorus (P) content in the soil, an element associated with O.M., possibly from the use of simple superphosphate in planting. *Pinus bahamensis* has a significant difference in soil chemical variables grouped in F2 ($H^{+}+Al^{+3}$), and *Eucalyptus* trees have a significant difference for the lowest levels of these variables grouped in F2.

Figure 4. A. Two-dimensional plane of factors F1 and F2 showing the clusters formed during factor analysis and distribution of other variables studied. B. Result of Fisher's exact test at 5% ($p<0.05$) for factors F1 and F2, considering ground cover as main treatments. C and D. Results of Fisher's test at 5% ($p<0.05$) in univariate analysis, considering ground cover as main treatments, Batatais, SP, Brazil



This shows that soil management is independent of tree cover, whether native or exotic, given that the history of pasture with *Aristida* spp. before afforestation may have influenced the result obtained, while management with exotics for more than six decades resulted in the improvement of their agricultural fertility. According to Novak *et al*. (2021), in natural soils or in the process of recovery, the potential acidity of the soil may be related to the leaching or adsorption of cations of pH basic of the exchange complex, such as Ca^{2+}, Mg^{2+}, K+ and Na+, and the resultant accumulation of acidic cations, such as Al^{3+} and H^{+}.

4 CONCLUSIONS

The multivariate analysis of soil attributes in afforestation was not significant for the native species studied, indicating homogeneity of soil in each treatment and that any changes found in the native species are the result of genetic and/or environmental factors, but not related to chemical attributes of the studied soil. However, multivariate analysis was also performed for other covers, and the results were highly significant for treatments based on the analysis of factors, showing difference in soil chemistry according to the soil covers evaluated.

The correlation between variables of factors (F1 and F2) results from the correlation among soil attributes. For example, low pH values are a function of the amount of Ca and Mg, which, when added to K, results in the sum of bases (SB) and, consequently, base saturation (V%), showing that one value depends on another. The values obtained for soil attributes in five soil covers in recent years show that *Eucalyptus* has a higher base content than Forestry and *Pinus*, resulting in less potential acidity and greater cation exchange capacity. Afforestation stands out for greater potential acidity and lower cation exchange capacity, possibly from the previous history of land cover with *Urochloa* spp. pasture.

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