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Soil physical, chemical, and microbiological attributes under *Pinus taeda* on different soil taxonomy in southern Brazil

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RESUMO: *The plantations of Pinus taeda L. in southern Brazil are installed on different soil taxonomy with different soil quality and production capacities. The soil quality can be evaluated by the means of different attributes which can additionally be related to the site productivity. In this study, we evaluate some soil physical, chemical, and microbiological attributes under Pinus taeda plantations aiming to identify the influence of soil taxonomy and silvicultural management on the quality of the soil. The soil was collected at 18 months, on Oxisols, Ultisols, and Inceptisols. Soil microbial biomass was performed by irradiation in a microwave and determined in a Vario TOC Cube, Elementar, Germany. Sites 3, 4, and 5 showed higher average values of soil microbial biomass, compared to sites 1 and 2, a fact possibly related to edaphic soil attributes and the previous management with minimal tillage in some sites. These results suggest that soil pedogenesis in combination with silvicultural management are determinant factors of the soil quality which is expressed by the physical, chemical, and microbiological attributes of the soil.*

Keywords: microbial biomass carbon, soil organic matter, forest management, soil microbial activity.

Introduction

The quality of the soil depends, among other factors, on the soil taxonomy, the environmental conditions, and the silvicultural management (Albaugh et al., 2017; Hedo et al., 2015). Thus, soil pedogenesis and silvicultural management are responsible for many of the edaphic attributes in the soil which are associated with soil quality (Zucon et al., 2020). Very fw studies evaluated soil attributes under *Pinus taeda* on different edaphoclimatic conditions in Southern Brazil. And evaluation of the physical, chemical, and microbiological soil attributes is widely useful to characterize the soil nutrient dynamics in different silvicultural management practices in *Pinus taeda* plantations (Tulio et al., 2022). This study evaluated some soil physical, chemical, and microbiological attributes under *Pinus taeda* plantations aiming to identify the influence of soil taxonomy and silvicultural management on the quality of the soil**.**

Materials and methods

Study Area and Experimental Design

The research sites are part of the Cooperative Program on *Pinus* Research in Brazil (PPPIB), coordinated by the Institute of Forestry Research and Studies (IPEF). The predominant climate in the areas is humid subtropical and classified by Köppen as Cfb. The study was carried out in five experimental plots of *Pinus taeda* planted in 2019, in Santa Catarina and Paraná states, southern Brazil.

The sites were selected because of their differences in soil taxonomy, and differences in soil physical and chemical attributes (Table 1). But there were also differences concerning the soil use before the present plantation with *Pinus taeda*, and for soil management (Table 2).

Table 1. Location and soil taxonomy of experimental areas of *Pinus taeda* in southern Brazil.

Areas	Municipality/State	Latitude	Altitude	Soil
Site 1	Telêmaco Borba/Paraná	24º22'57.76'' S	835	Oxisols
Site 2	Lages/Santa Catarina	27º79'28.72'' S	916	Ultisols
Site 3	Caçador/Santa Catarina	26º74'86.67'' S	1030	Oxisols
Site 4	Vargem Bonita/Santa Catarina	26º55'31.71'' S	1088	Oxisols
Site 5	Campo Belo do Sul/Santa Catarina	28º00'29.00'' S	956	Inceptisols

Table 2. Characteristics of silvicultural management in the experimental plots.

Areas	Previous soil use	Soil management	Spacing
Site 1	*Eucalyptus urophylla*	Removal of residues / Subsoiling 60 cm	3.1 m x 1.9 m
Site 2	*Pinus taeda*	Removal of residues / Subsoiling 50 cm	2.4 m x 2.6 m
Site 3	*Pinus taeda*	Minimal tillage / Subsoiling 60 cm	2.5 m x 2.5 m
Site 4	*Pinus taeda*	Removal of residues / Subsoiling 35 cm	2.5 m x 2.0 m
Site 5	*Pinus taeda*	Minimal tillage / Subsoiling 45 cm	3.0 m x 2.5 m

Soil Sampling and Analysis

Soil samples were analyzed for pH $CaCl_2$ 0.01 M; exchangeable Al^{3+}, Ca^{2+}, and Mg^{2+} extracted by KCl 1M, available K^+ and P extracted by Mehlich I, ($H^+ + Al^{3+}$) by calcium acetate 0.5 M at pH 7.0. Total carbon and nitrogen were obtained by combustion with the Elementar Vario EL III analyzer. The soil microbial biomass was analyzed on air-dried and sieved (2mm mesh) soil

samples, which were moistened to field capacity. Microbial Biomass Carbon (MBC) and Microbial Biomass Nitrogen (MBN) were performed by irradiation in a microwave oven for 2 minutes. Briefly, one of the two sets of soil samples was irradiated, and the other set of soil samples was not irradiated. Subsequently, all samples were extracted with a K_2SO_4 (0.5 M). The MBC and MBN were determined in a Vario TOC Cube, Elementar analyzer.

Statistical analysis

Analysis of variance and Tukey's test ($P<0.05$) for average comparisons were performed using the Rstudio software (R Development Core Team, 2016) and the statistical package 'ExpDes' in R version 1.2.2.

Results and discussion

Concerning the physical and chemical attributes of the soils (Table 3), small variations were observed between depths. Site 1 showed the lowest values of clay, carbon, and macro-nutrients in the surface depth. Sites 3, 4, and 5 were the sites with the highest values of clay and nutrients.

Table 3. Soil chemical and physical attributes in the 0-5 and 5-10 cm soil depth of the sites of *Pinus taeda* of the initial growth in southern Brazil.

Sites	Depth	Clay	pH	C	N	P	K	Ca	Mg	BS	m
	cm	g kg^{-1}	$CaCl_2$	--g kg^{-1}--		mg kg^{-1}	-----cmolc dm^{-3}-----			------%------	
1	0-5	300	3.9	21.8	1.2	2.8	0.06	1.5	0.62	19.2	44.7
	5-10	313	4.0	19.8	1.2	6.0	0.05	1.5	0.51	18.8	43.6
2	0-5	625	4.1	32.0	1.9	3.9	0.13	2.7	1.12	27.1	30.5
	5-10	575	4.1	27.5	1.7	3.3	0.08	2.3	0.99	24.4	38.4
3	0-5	750	3.9	53.0	2.5	5.9	0.15	5.6	0.99	32.3	34.1
	5-10	713	3.9	44.5	2.1	4.8	0.13	5.1	0.88	30.4	36.1
4	0-5	714	4.4	42.9	2.4	3.4	0.14	1.3	0.42	11.0	66.4
	5-10	711	4.4	39.9	2.3	3.0	0.12	1.3	0.33	10.5	66.2
5	0-5	619	4.4	48.3	2.7	6.2	0.17	2.4	0.68	18.5	52.3
	5-10	623	4.4	41.4	2.4	4.7	0.10	2.0	0.47	15.0	59.4

pH ($CaCl_2$ 0.01 mol L^{-1}); Ca^{2+}, and Mg^{2+} (extracted with KCl 1 mol L^{-1}); total carbon (C) and nitrogen total (N) (total combustion method); K+, P, (Mehlich^{-1}); Base saturation (BS); Al^{3+} saturation (m).

The values average of MBC and MBN were not influenced by the depth of soil sampling. However, there were differences between the five sites (Table 4), with site 5 showing the highest values, followed by sites 3 and 4, and the lowest values of MBC for sites 1 and 2. The differences identified for the microbiological attributes in the soil were related to site-specific conditions (soil taxonomy and silvicultural management). Despite all the sites having the same species and with similar ages in the present, the previous use of the soil was quite different among the sites.

Table 4. Microbial biomass carbon (MBC) and microbial biomass nitrogen (MBN) at the depths of 0-5 and 5-10 cm, in sites of *Pinus taeda* in Southern Brazil. Means followed by the same letter in a column do not statistically differ (P<0.05) by Tukey's test. CV: coefficient of variation.

Areas	MBC	MBN	MBC	MBN
	0-5 cm (mg C kg-1 soil)		5-10 cm (mg kg-1 soil)	
Site 1	240 a	15 a	261 a	20 a
Site 2	454 a	26 a	495 a	29 ab
Site 3	1186 b	25 a	1247 b	29 ab
Site 4	1320 b	54 b	1242 b	51 b
Site 5	1962 c	122 c	2106 c	101 c
CV %	36	57	47	61

The effects on soil microbiological attributes are not related to the species planted (Samuelson et al., 2009), but rather to edaphic conditions resulting from the history of soil use and the management of the forest system of the sites (Ward et al., 2015). For MBC and MBC, site 5 showed the highest values, and site 1 the lowest ones. Site 1 presented the lowest clay content in the soil among all sites and had previous soil use with *Eucalyptus urophylla* which may explain part of the results. All other sites had *Pinus taeda* before the actual plantation. The quality of the remaining organic matter certainly influenced the soil microbial biomass (Harrison et al., 2014; Fine et al., 2018). Most of the residues from tree harvest were removed from site 1 before planting *Pinus taeda* and possibly was a determining factor for low values of soil microbiological activity. Regarding the chemical attributes, site 1 presented the lowest levels of C, N, K, Ca, and Mg in both soil depths. Therefore, many edaphic conditions of site 1 could be related to the lowest values for its microbiological attributes.

Conclusions

The results indicate that edaphic factors act in a site-specific way on soil microbial biomass with influence from the soil type but also with the relevant effect of land use and forest management (system of harvesting/soil preparation) on the results. MBC and MBN varied according to management practices and soil taxonomy. Therefore, monitoring these attributes is an important way to evaluate changes in soil quality.

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