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PHYSICAL PROPERTIES OF SOILS IN RELATION TO EUCALYPT GROWTH

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ABSTRACT

Meagre data exist in Kerala on the physical parameters of soils and their relation to eucalypt growth. Literature points to the influence of depth of soil, texture structure, stoniness, bulk density, permeability, aeration, infiltration, and water-holding capacity on tree growth. Present project aims at an indepth elaboration of soil physical properties and their relation to height growth of *Eucalyptus tereticornis* and *E grandis* in one site each. Kondazhi in Trichur and Muthanga in Kozhikkod Forest Divisions were the respective study areas. Four plots, 10x10 m for Kondazhi and 12.5x12.5 m for Muthanga, within a radius of 500 m were demarcated and 0-20, 20-40 and 40-60 cm depths were sampled from three pits in each plot. Top height and girth (gbh) of 5-7 trees were also measured.

Gravel, sand, silt, and clay contents are reported as percentages of the whole soil (gravel+sand+silt+clay= 100) and interpretations are better with this approach than the conventional method of sand + silt + clay = 100. Soil data are being discussed for 0-20, 20-40 and 40-60 cm depths and for 0-60 by summation. Among the properties, gravel is the most and particle density the least variable. Sand, silt and clay contents are highly variable, whereas water-holding capacity, pore space and bulk density are intermediate. Intercorrelations of properties bring out consistency in the data. In Kondazhi significant correlation exists for gravel sand, silt, clay, bulk density, pore space, and water-holding capacity with tree height; however it is only for gravel and sand in Muthanga. Correlation is consistent for gravel and sand in both sites. Principal component analysis reveals that a large part of the variation in height is explainable by the first and second components. Gravel, sand and water-holding capacity stand out among the physical properties and these appear to influence the height growth of eucalypts in Kondazhi and Muthanga sites.

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Key words **: Soil physical properties, height growth, *Eucalyptus tereticornis, E. grandis.***

INTRODUCTION

Soil physical, chemical and biological parameters influence forest tree growth. While investigations are being undertaken on different aspects of soils in eucalypt plantations (Alexander et al 1981, Balagopalan & Alexander 1983, Sankar et al 1985), an indepth look into the physical properties can ascertain which of these have bearing on the growth of trees. Studies elsewhere have thrown light on several with the following corning to the forefront: depth of soil, texture, structure, stoniness, bulk density, permeability, aeration, infiltration, and water-holding capacity (Armson 1577, Carmean 1975, Coile 1952, FA0 1979, Hartsge 1984, Lal & Greenland 1979, Pritchett 1979). Physical properties of soils under eucalypts in Kerala have not been studied much and little information exists on their effect on eucalypt growth The present project aims at indepth elaboration of soil separates, bulk and particle densities, pore space, and maximum water-holding capacity properties and their relation to height growth of *Eucalyptus tereticornis* and *E. grandis* in one site each.

MATERIALS AND METHODS

Kondazhi (10°42'N, 76°24'E) in Trichur and Muthanga (11°40'N, 76°22'E) in Kozhikkod Forest Divisions were the respective study areas. The former has 3977 *Eucalyptus tereticornis* plantation whereas the latter has 1980 *E grandis* Kondazhi is at 100 m asl with mean annual temperature and rainfall around 27 C and 3000 mm (George 1955). The parent material is gneiss and soil pits have dark to reddish brown, granular and friable surface with dark red to reddish brown, massive and firm subsurface layers. Muthanga in the southern tip of Wynad tableland, is at 800 m asl with mean annual temperature and rainfall around 22 C and 1700 mm (Iyer 1964). The parent material is gneiss with hornblende-biotite dominance. Soil pits have dark to very dark greyish brown, granular and very friable to friable surface with dark reddish to yellowish brown, massive and firm subsurface layers. Roots are plentiful in the surface layers of both sites.

Four plots, 10 x 10 m for Kondazhi and 12.5 x 12.5 m for Muthanga, were demarcated to have 20 trees in each and the plots were within a radius of 500 m. Three soil pits were dug in each plot and samples were collected from 0-20, 20-40 and 40-60 cm depths. Simultaneously 1000 cm^3 cores were taken for determining bulk density. Top height and girth (gbh) measurements of five to seven trees were also done in every plot. Soil samples were air-dried, cleaned off visible roots and passed through 2 mm sieve. Gravel (2-75 mm) content was determined from the weight of material retained on the sieve and gross weight of soil sample. Particle-size (sand–0.02-2, silt=0.002-0.02 and clay $<$ 0.002 mm), bulk and particle densities, and pore space analyses were based on the procedures in ASA Monograph (1965). Maximum water-holding capacity was assayed by saturation of soil columns.

RESULTS AND DISCUSSION

Average data, based on three soil pits in every plot, are presented in Tables 1 and 2. Depth-wise means and coefficients of variation are computed from the data

Table 1. Soil physical properties in Kondazhi site

Plot/	depth (cm)	Gravel	Sand	Silt	Clay	Bulk density	Particle density	Pore space	Maximum water-holding capacity
		(.....	...%...	..	..........)	(.....g cm^{-3}	)	(	...%.........)
I	00-20*	6	68	8	18	1.34	2.50	46	32
	20–40	15	56	9	20	1.22	2.47	50	40
	40-60	21	54	7	18	1.33	2 45	46	37
II	00–20	46	45	4	5	1.66	2 55	35	22
	20–40	51	**39**	4	6	1.48	2.52	42	29
	40–60	57	31	5	7	1.66	2 60	36	26
III	00–20	24	54	9	13	1.45	2.42	40	35
	20–40	45	40	5	10	1.39	2.44	43	34
	40–60	62	27	4	7	1.39	2.45	43	36
IV	00–20	12	67	9	12	1.35	2.45	45	36
	20–40	11	63	10	16	1.28	2.44	47	36
	40–60	8	65	11	16	1.34	2.45	45	36
Mean**									
	00–20	22	58	8	12	1 45	2.48	42	31
	20–40	30	50	7	13	1.34	2.47	46	35
	40–60	37	44	7	12	1.43	2.49	42	34
	00–60	30	51	7	12	1.41	2.48	43	**33**
Coefficient of variation (%)									
	00–20	75	17	30	42	10	**3**	14	18
	20–40	65	24	39	48	12	2	13	16
	40–60	73	42	43	52	10	4	12	16
	00–60	65	26	31		10	2	11	15

* Average of three soil pits in each plot; ** mean and cv based **on** twelve soil pits.

Table 2. Soil physical properties in Muthanga site

Plot / depth (cm)	Gravel	Sand	Silt	Clay	Bulk density	Particle density	Pore space	Maximum water-holding capacity
	(………………	%	……………………	)	(….. g cm^{-3}	…..)	(………%	……)
I 00-20*	17	64	10	9	1.43	2.46	42	36
20–40	21	59	10	10	1.62	2.56	37	32
40–60	3%	47	6	9	1.65	2.49	34	**30**
II 00–20	1	72	12	15	1.41	2.54	44	42
20–40	2	71	12	15	1.46	2.56	43	37
40–60	6	67	11	16	1.51	2.63	43	37
III 00 -20	0	80	10	10	1.43	2.51	43	37
20–40	0	78	9	13	1.60	2.52	37	34
40–60	0	77	10	13	1.59	2.59	39	35
IV 00–20	1	82	7	10	1.58	2.57	39	32
20–40	0	78	9	13	1.63	2.49	35	33
40–60	0	76	8	16	1.51	2.50	40	34
Mean**								
00–20	5	74	10	11	1.46	2.52	42	37
20–40	6	71	10	13	1.58	2.54	38	34
40–60	11	67	9	13	1.56	2.55	39	34
00–60	7	71	10	12	1.54	2.54	40	35
Coefficient of variation (%)								
00–20	164	11	21	21	6	2	*8*	11
20–40	172	12	18	19	5	2	9	11
40–60	178	23	24	**23**	6	4	11	11
00–60	180	15	16	19	3	2	7	9

* Average of three soil pits in each plot; **mean and cv based on twelve soil pits.

of twelve pits in a site. As distribution of physical properties in each depth may not bring out fully the relationship with tree height, summation for 0–60 cm is also tried simultaneously. Gravel, sand, silt and clay contents are expressed as percentages of the whole soil (gravel + sand + silt + clay= 100) and interpretations appear to be more meaningful with this approach than the conventional method of sand + silt + clay = 100. Where gravel is a major component of soils, this reasoning may prove useful. All properties are reported in per cent except bulk and particle densities which are in g cm^{-3}.

Soil Physical Properties

Gravel (G) : Rounded and subrounded fragments of 2–75 mm diameter are included in gravel. In many plantations, gravel occupies a major portion of soil volume thus reducing the space for other separates and pores. Gravel can depress tree growth if it occupies significant volume in coarse soils (Armson 1977, Pritchett 1979, Raupach 1967). Among the physical properties studied, gravel is the most variable and the occasional stunting or lack of height growth of eucalypts can partly be ascribed to this type of gravel distribution (FAO 1979). Gravel content is markedly higher in Kondazhi.

Sand, Silt and Clay (S, Si, C) : Proportion of sand, silt and clay determines soil texture and generally the productivity increases as the proportion of material smaller than 0.02 mm reaches an optimal level (Pritchett 1979). The data clearly show that Muthanga has more sand than Kondazhi and it decreases with depth in both sites. The values of sand, silt and clay are quite variable in both cases.

Bulk density [BD) : BD is the mass of dry soil per unit bulk volume. In soils with considerable gravel content, its determintation is subject to errors, as in the case of Kondazhi. Generally BD increases with depth in forest soils (Armson 1977). BD decreases with depth in Kondazhi and reverse occurs in Muthanga and its values vary little in both sites.

Particle density (PD): PD is the mass per unit volume of soil particles and it is more or less a permanent characteristic of the soil. PD is the least variable among the properties. Muthanga has slightly higher PD values than Kondazhi.

Pore space(PS): PS is the total space not occupied by soil particles in a bulk volume of soil and in this report it is a derived property from BD and PD. PS values do not vary much and these do not follow any consistent trend in both the sites.

Maximum water-holding capacity (WHC): WHC is approximately the field moisture capacity referred to in literature. The variability of WHC is not as great as that for gravel, sand, silt, and clay and it is more in Kondazhi than in Muthanga.

Intercorrelation of Soil Physical Properties

Significant negative correlation exists between G and S/Si/C in all the layers of Kondazhi and 40-60 cm of Muthanga (Tables 3-4). In the latter, correlation

Table 3. Coefficients of correlation for soil physical properties in Kondazhi site

Variable	C	S	Si	C	BD	PD	PS
00-20 cm depth							
S	-.97						
Si	-.81	.68					
C	-.92	.80	.77				
BD	.76	-.77	-.55	-.65			
PD	.31	-.19	-.46	-.40	.36		
PS	-.70	.75	.43	.56	-.95	-.07	
WHC	-.78	.71	.85	.68	-.81	-.62	.67
20-40							
S	-.98						
Si	-.98	.95					
C	-.93	.86	.91				
BD	.68	-.60	-.72	-.74			
PD	.30	-.26	-.34	-.31	.47		
PS	-.65	.57	.69	.72	-.98	-.28	
WHC	-.83	.73	.81	.94	-.78	-.49	.72
40-60							
S	-.99						
Si	-.95	.96					
C	-.94	.91	.82				
BD	.53	-.50	-.47	-.59			
PD	.45	-.41	-.35	-.57	.61		
PS	-.43	.42	.40	.46	-.95	-.35	
WHC	-.51	.46	.45	.62	-.94	-.70	.86
00-60							
S	-.98						
Si	-.93	.89					
C	-92	.85	.86				
BD	.78	-.73	-.74	-.80			
PD	.47	-.42	-.49	**-.53**	.60		
	-.77	.73	.71	.77	-.97	-.39	
WHC	-.86	.80	.84	.89	-.87	-.62	.81

r-values for 10df = .58 and .71 at 95 and 99% levels.

Table 4. Coefficients of correlation for soil physical properties in Muthanga site

Variable	C	S	Si	C	BD	PD	PS
***00-20* cm depth**							
S	-.88						
Si	-.10	-.36					
C	-.40	-.06	.73				
BD	-.22	.48	-.76	-.22			
PD	-.40	.38	-.24	.29	.36		
PS	.15	-.43	.72	.33	-.94	-.02	
WHC	02	-.45	.91	-.69	-.75	*-.05*	.79
20–40							
S	-.95						
Si	- 11	-.14					
C	-.73	.53	.24				
BD	.12	.12	-.48	-.56			
PD	.28	-.46	.45	.15	-.30		
PS	-.01	-.26	.54	.55	-.95	.56	
WHC	- 48	.24	-.65	.70	-.46	.16	.49
40–60							
S	- 99						
Si	-.74	.66					
C	-.89	.83	.67				
BD	.61	-.55	-.56	-.75			
PD	-.16	.10	.39	.21	-.07		
PS	-.58	.49	.68	.71	-.85	.59	
WHC	-.84	*.80*	.74	.84	-.64	.11	.59
00–60							
S	-.97						
Si	-.45	.26					
C	-.75	.60	.59				
BD	.31	-.10	-.77	-.66			
PD	-.28	.12	.59	.55	-.44		
PS	-.28	.06	.81	.69	-.96	.65	
WHC	-.50	.31	.82	.74	-.82	.53	.84

r-values for 10 df = 0.58 and .71 at 95 and 99% levels.

between **G** and S is good in the three depths, G and Si in 40-60, and **G** and C in 20-40 and 40–60 cm. BD is positively correlated with G in 0-20 and 20-40 cm of Kondazhi and the 40-60 cm depths of Muthanga. PD is not well correlated with G. **PS** is negatively correlated with G in 0-20 and 20-40 cm depths of Kondazhi and in the 40-60 cm of Muthanga. The same pattern is followed by WHC.

The positive correlation between S/Si/C and PS / WHC in the three depths of Kondazhi is consistent and it is maintained in the 40-60 cm of Muthanga. In the latter, aberration occurs between S and PS/WHC in the 0-20 cm depth; however, consistency is maintained between Si/C and PS/WHC. Between BD and PS/WHC, significant negative correlation exists in all the depths of Kondazhi and 0-20 and 40-60 cm of Muthanga. In the 20-40 cm layer of Muthanga BD and PS are strongly correlated but not BD and WHC. Significant positive correlation is observed between **PS** and WHC in all depths except 20-40 cm of Muthanga. When coefficients for 0-60 cm depth are compared, the differences noted between the two sites are dampened and consistent correlations such as G with S/Si/C (-), Si/C with PS/WHC (+), BD with PS/WHC (–), and PS With WHC (+) come through.

Soil Physical Properties vs Eucalypt Growth

Correlation coefficients between soil physical properties and height growth in Kondazhi and Muthanga (Tables 5-6) are based on a limited number of four plots in each site and hence they are suggestive. Only correlation coefficients of 0.70 and greater are considered for discussion.

Table 5. Mean height and girth of eucalypt trees in Kondazhi and Muthanga sites

Variable		I	II	III	IV plot
Kondazhi*					
height (rn)	m	10.5	7.3	7.4	10.8
	cv	14	25	16	13
girth (cm)	m	28.9	27.0	28.0	25.4
	cv	26	24	12	12
Muthanga **					
height (m)	m	10.2	12.1	12.6	15.8
	cv	52	27	22	73
girth (cm)	m	26.1	29.2	30.4	35.9
	cv	40	38	35	13

* 1977 *Eucalyptus tereticornis;* data as of April 1984; n 5 in I – IV.

** 1980 *E. grandis;* data as of April 1983; n=5 in 1-11, 7 in III and 6 in IV.

rn= mean; cv= coefficient of variation %

Table 6. Coefficients of correlation between soil physical properties and height of eucalypt trees

Property	0–20	20–40	40–60	0–60 cm depth
		Kondazhi site		
Gravel	-.85	-.99	- 99	-.99
Sand	.94	.98	.98	.99
Silt	.51	.99	.87	.97
Clay	.63	.92	.98	.90
Bulk density	-.82	-.92	-.72	-.83
Particle density	-.14	-. 42	-.59	-.49
Pore space	.91	.92	.76	.91
Water-holding capacity	.53	.81	.62	.87
		Muthanga site		
Gravel	-.69	-.75	-.77	-.75
Sand	.88	.82	.79	.84
Silt	-.73	-.43	.20	-.41
Clay	-.02	.44	.76	.51
Bulk density	.87	.23	-.74	.18
Particle density	.90	-.91	-.12	.06
Pore space	-.75	-.40	.39	-.31
Water-holding capacity	-.56	.01	.39	-.18

r-values for 2 df = .95 and .99 at 95 and 99% levels.

Height is negatively correlated with gravel in all the layers of Kondazhi and Muthanga. It is so with BD in the three depths of Kondazhi and 40-60 cm of Muthanga. In the latter site, positive correlation is observed in 0-20 cm depth. Sand,and silt clay are positively correlated in Kondazhi 20-40 and 40-60 cm layers and only sand in Kondazhi 0-20 cm. Sand is positively correlated in all the depths of Muthanga and clay only in 40-60 cm depth. Negative correlation exists for silt in 0-20 cm depth of Muthanga. Particle density does not follow any consistent trend. Pore space has positive correlation in Kondazhi layers and negative in 0-20 cm of Muthanga, Water-holding capacity is positively correlated only in 20-40 cm layer of Kondazhi. When 0- 60 cm depths are studied, consistent correlation occurs only for gravel and sand. In Kondazhi, strong correlation exists for silt, clay, bulk density, pore space, and water-holding capacity; however, in the case of Muthanga these are not correlated.

Because there are eight variables in this study, with some correlated to height and Some not, multivariate analysis could determine the combined or independent contribution of these to the variation in tree height (Jeffers 1978). Principal component analysis is such a tool and it involves the reduction of dependent variables to a few master variables termed principal components. The later are composed of various loadings of the original variables based on covariance (Richardson and Bigler 1984). This analysis involves extraction of eigen values and eigen vectors from the matrix of correlation coefficients of the original variables. Eigen values account for the variability and eigen vectors for the contribution of the variables in each component.

Principal component analysis of the soil data indicates that 78-91% of the variation in physical properties could be explained by the first two Components (Table 7).

Table 7. Regression of principai components with height of eucalypt trees

Depth (cm)	Cumulative variability explained by the first two principal components	Partial regression coefficients		R^2
			P2	
site				
00–20	**88**	**-.72**	**1.28**	**.90**
20–40	**90**	**-.42**	**.55**	**.98**
40–60	**91**	**-.31**	**.36**	**.91**
00-60	**91**	**1.78**	**2.13**	**.26**
Muthanga site				
00-20	**82**	**-1.13**	**-.46**	**.98**
20–40	**78**	**-.22**	**.01**	**.36**
40–60	**83**	**–.20**	**.04**	**.69**
00–60	**84**	**-.30**	**1.57**	**.81**

P1 and P2 are the first and second principal components; R^2=coefficient of determination.

Multiple linear regression of these components with tree height reveals fairly high values of coefficients of determination which explain the variation in height for 0-20, 20-40 and 40-60 cm of depths of Kondazhi and 0-20 and 40-60 cm Muthanga. The value for Kondazhi 0-60 cm is low whereas that for Muthanga 0-60 cm depth is high. The following variables stand out in the analysis : gravel, sand and water-holding capacity in Kondazhi; and gravel, sand, silt, and water-holding capacity in Muthanga. In common, gravel, sand and water-holding capacity appear to influence the height growth in Kondazhi and Muthanga sites.

CONCLUSION

Among the properties, gravel is the most and particle density the least variable. Sand, silt and clay contents are highly variable; whereas water-holding capacity, pore space and bulk density are intermediate. In Kondazhi, good correlation exists for gravel, sand, silt, clay, bulk density, pore space, and water-holding capacity properties with tree height; however, it is only for gravel and sand in Muthanga. Principal component analysis reveals that a large part of the variation in height is explainable by the first two principai components. Gravel, sand and water-holding capacity stand out among the physical properties and these seem to influence the height growth of eucalypts in Kondazhi and Muthanga

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