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SOILS IN TEAK PLANTATIONS OF DIFFERENT SITE QUALITY

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ABSTRACT

Though there were a few soil studies in selected teak plantations of Kerala, none had been conducted specifically on soil properties in relation to site quality (SQ). This project restricted to six plantation transects of Arienkav, Mannarappara, Pothupara, Nellikkutha, Kurichiad and Begur areas aimed to bring out the soil parameters influencing SQ.

In each transect of 500 m length and 100 m width, 100 x 100 m plots were marked and a group of dominant trees (5-7) identified. Measured top height of these trees and based on the height attainable at 50 years, computed SQ. From a soil pit in the centre of these trees, collected 0-20, 20-40 and 40-60cm depth samples. Bulk density, gravel, particle-size separates, maximum water-holding capacity of unsieved soil, pH (20:40 water), organic carbon, exchange acidity and exchangeable bases analyses were done. The contents of sand, silt, clay, organic carbon, exchange acidity and exchangeable bases were adjusted for gravel content; and 0-60 cm soil parameters were composited from the 0-20, 20-40 and 40-60 cm depth values for relating to SQ.

Analysis of variance of one-way classification of age/SQ groups showed significant differences in soil properties among groups. Increase of gravel and exchange acidity and decrease of sand, silt, pH and exchangeable bases resulted in lower SQ along a transect and generally across transects. Bulk density, clay, water-holding capacity and organic carbon trends were inconsistent. In a multiple linear regression analysis, soil variables accounted for 31% of the variation in top height and age 63%. Partial regression coefficients pointed to the prominent effects of gravel, sand, pH and exchange acidity. Thus, the variation in SQ along and across the six transects was explainable in terms of soil parameters. Field attempts to enhance SQ, with due weightage to gravel, sand, pH, exchange acidity, exchangeable bases and other relevant site parameters are implicated.

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Key words : Teak soils, physical and chemical properties, site quality.

INTRODUCTION

Site is a mosaic of climatic, biotic, soil and other locational factors which can be understood or rated by comprehending the physical, chemical and biological properties and processes of soil on which a tree crop is established. Site quality (SQ) is the composite of physiological make-up of a tree and environmental variables and it is essentially synonymous with productivity rating in agriculture. However, in forestry the productivity rating is confounded by the long rotation of tree crops and attendant modification of environment by the growing trees. Site index, the height attained by dominant trees at a base age nearest to the harvesting age, is an accepted measure of SQ in forestry (Srivastava & Ulrich 1978. Hocker 1979, Hagglund 1981). Height is a good indicator of site productivity because trees on poor sites do not grow as tall as those on good sites and it is minimally affected by the normal stand density in plantations.

Literature presents several studies on soils in teak plantations (Gupta 1950, Banijbhatana 1956, Yadav 1969, Watterston 1971) and an article by Seth &Yadav (1978) gives the gist of teak autecology. Previous studies in Nilambur teak plantations ascribe good SQ to high silica-sesquioxide ratio, alluvial soils, moisture availability. drainage, sandy loam texture and higher levels of bases (Davis 1940, Laurie & Griffith 1942). It is the general observation that good-quality teak is restricted to strips along river banks and further inwards there is lowering of the quality.

Though there were a few studies on the soils in teak plantations of Kerala (Griffith & Gupta 1947, Jose & Koshy 1972, Alexander et a1 1981, 1984), none had been conducted specifically on soil properties in relation to SQ. The present investigation restricted to six plantation transects aims to bring out the soil parameters influencing SQ.

STUDY TRANSECTS, SOILS AND METHODS OF ANALYSIS

Study transects were selected in teak plantations of Arienkav, Mannarappara, Pothupara, Nellikkutha, Kurichiad and Begur areas (Fig 1). These transects belong to Thenmala, Konni, Malayattur, Nilambur, Kozhikkod and Wynad Forest Divisions respectively. In each plantation, marked plantation strip of 500 m length and 100 m width to represent different slope positions. In the strip, demarcated plots of 100 x 100 m and identified the dominant group of teak trees, generally 5-7 in number and top height and girth of these trees (gbh) were measured. Computed SQ for each plot based on the height attainable at 50 years which is close to the harvesting age (FRE Colleges 1970).

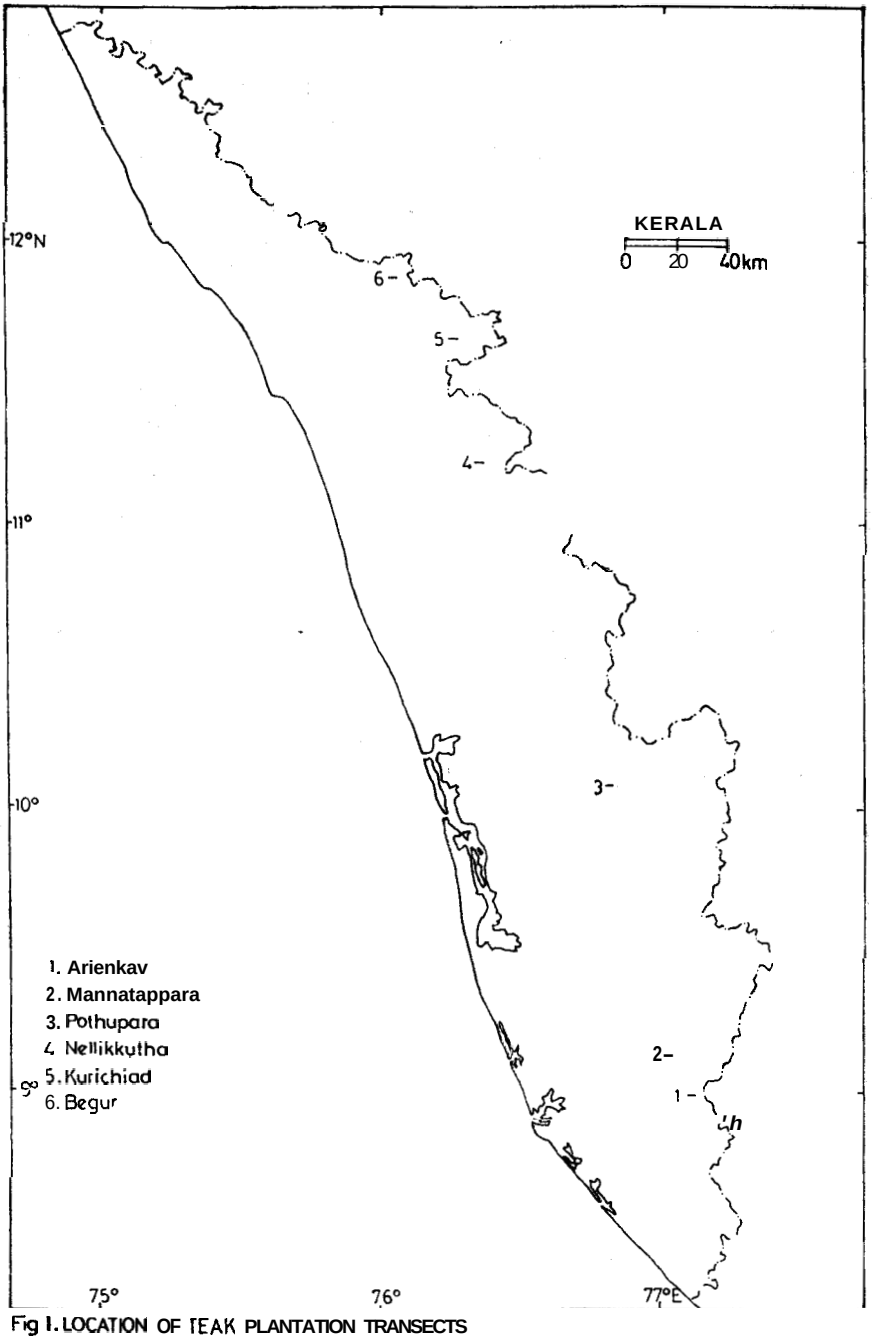

Fig 1. LOCATION OF TEAK PLANTATION TRANSECTS

Soil pit was dug in the centre of dominant group of trees in each plot- and soil samples were taken from 0-20, 20-40 and 40-60 cm depths. Bulk density was assayed by taking cores from each depth. Air-dried the samples,

cleaned off visible roots and passed the samples through 2-mm sieve. Calculated the gravel (2-75 mm) content from the weight of material retained on the sieve and gross weight of soil. Following soil analyses were carried out on the <2 mm portion based on the procedures in ASA Monograph (1965) and Jackson (1958): sand, silt and clay (20-2000, 2-20 and <2 um) by hydrometer; pH in 20:40 soil–water suspension; organic carbon by potassium dichromate-sulphuric acid wet digestion; exchange acidity by 0.5 N barium acetate; and exchangeable bases by 0.1 N hydrochloric acid. Determined maximum water–holding capacity (WHC) by saturation of unsieved soil columns.

RESULTS AND DISCUSSION

Tree Parameters

Tree parameters measured were top height of dominant group of trees in a plot and girth at breast height (Tables 1-6). Correlation was attempted between age-height, age-girth and height-girth of all trees in the six transects (n = 158). Coefficients of correlation, 0.658 for height vs age, 0.725 for girth vs age and Q.762 for girth vs height indicate the regularity of teak stands. Among the 29 plots across different teak plantations ranging in age from 14 to 65 years, two are from SQ I (305-366 dm), four from I1 (244-304 dm), twelve from I11 (183-243 dm) and eleven from IV (122-182dm).

Soil Parameters

As distribution of physical and chemical properties of 0-20, 20-40 and 40-60 cm depths singly would not bring out fully the relationship between soils and SQ, 0-60 cm values composited from the values of three depths are presented in Tables 1-6 and Fig 2; ranges of properties for the three depths are given in Table 7.

Because gravel (2-75 mm) is an unavoidable component in forest soils of Kerala, the contents for sand, silt, clay, organic carbon, exchange acidity and exchangeable bases have been weighted for it. Thus, their quantities in the whole soil are reported instead for < 2 mm portion of soil comprising sand, silt and clay only. Coefficients of correlation between soil parameters with and without weightage of gravel (Table 8) demonstrate better relationships when weightage is done for gravel content. What stands out clearly is the negative and consistent correlation between gravel and sand, silt, clay, organic carbon, exchange acidity and exchangeable bases. The need for weightage of gravel was also brought out in an earlier study on soil physical properties and eucalypt growth (Alexander & Thomas 1985).

The elevation, slope, stand and soil parameters along each transect are presented plot-wise in Tables 1-6 and Fig 2. As there are age differences between the transects, one-way classification into eleven age/SQ groups (Table 9) was attempted for examining the influence of elevation. slope and soil properties on SQ across the transects.

Table 1. Site, stand and soil (0-60 cm) parameters in Arienkav transect of 1920 teak plantation

Parameter	Plot (100 X 100 m) 1	2	3	4	5
Elevation (m)	350	320	305	245	180
Slope (degree)	10	5	20	35	0
Stand density (trees/ha)	122	104	157	108	79
Trees around soil pit	6	6	6	6	6
Dominant height (dm)	167	227	197	185	240
Gbh (cm)	120	140	99	106	171
Site quality	IV	I11	IV	IV	III
Bulk density (Mg/m^3)	1.41	1.26	1.44	1.25	1.42
% Gravel	41	22	39	41	27
% Sand	47	57	43	40	62
% Silt	5	7	4	6	4
% Clay	7	14	14	13	7
WHC (mm)	267	242	252	238	260
pH (20:40 water)	5.4	5.3	5.3	5.1	5.4
Organic carbon (g/kg)	11	7	6	6	6
Exch acidity (me/kg)	33	32	23	29	23
Exch bases (me/kg)	73	73	42	49	45

Table 2. Site, stand and soil (0-60 ctn) parameters in Mannarappara transect of 1932 teak plantation

Parameter	Plot (100 X 100 m 1	2	3	4	5
Elevation (m)	90	75	70	60	45
Slope (degree)	5	5	20	10	0
Stand density (trees/ha)	156	161	I47	131	103
Trees around soil pit	6	6	6	6	6
Dominant height (dm)	210	187	183	217	283
Gbh (cm)	118	128	I04	147	202
Site quality	I1I	IV	IV	I I I	I1
Bulk density (Mg/m3)	1.22	1.30	1.24	I.25	I.25
% Gravel	32	42	35	27	17
% Sand	51	38	45	53	56
% Silt	6	6	6	8	13
% Clay	11	14	14	12	14
WHC (mm)	253	23I	274	278	264
pH (20 : 40 water)	5.3	5.2	5.1	5.3	5.8
Organic carbon (g/kg)	8	7	7	10	12
Exch acidity (me/ kg)	32	27	33	39	36
Exch bases (me/kg)	64	47	52	63	I20

Table 3. Site, stand and soil (0-60 cm) parameters in Pothupara transect of 1971 teak plantation

Parameter	Plot (100 X 100 m) 1	2	3	4	5
Elevation (m)	70	50	60	70	30
Slope (degree)	16	10	12	16	7
Stand density (trees/ha)	437	543	598	703	512
Trees around soil pit	7	5	6	6	6
Dominant height (dm)	83	92	73	92	88
Gbh (cm)	53	67	34	49	58
Site quality	IV	IV	IV	IV	IV
Bulk density (Mg/m^3)	1.24	1.14	1.20	1.20	1.44
% Gravel	43	26	37	40	48
% Sand	41	57	47	44	36
% Silt	6	9	7	7	5
% Clay	10	8	9	9	I1
WHC (mm)	279	274	266	266	297
pH (20:40 water)	5.9	5.7	5.5	5.5	5.3
Organic carbon (g/kg)	7	12	7	9	5
Exch acidity (me/kg)	19	35	28	27	19
Exch bases (me/kg)	61	70	55	58	37

Table 4. Site, stand and soil (0-60 cm) parameters in Nellikkutha transect of 1937 teak plantation

Parameter	Plot (100 X 100 m) 1	2	3	4	5+
Elevation (m)	110	90	80	75	70
Slope (degree)	11	14	0	0	0
Stand density (trees/ha)	81	114	89	74	2
Trees around soil pit	5	4	5	5	2
Dominant height (dm)	260	260	376	339	300
Gbh (cm)	98	94	156	I29	148
Site quality	I1	I1	I	I	I1
Bulk density (Mg/m^3)	1.09	1.07	1.22	1.14	1.38
% Gravel	47	46	18	14	14
% Sand	35	37	63	70	77
% Silt	5	6	9	7	2
% Clay	13	11	10	9	7
WHC(mm)	263	279	286	237	224
pH (20.40 water)	5.3	5.6	5.8	5.7	6.1
Organic carbon (g/kg)	8	5	7	8	4
Exch acidity (me/kg)	24	12	21	23	11
Exch bases (me/kg)	44	44	92	78	55

+40 x 20 m.

Table 5. Site, stand and soil (0-60 cm) parameters in Kurichiad transect of 1942 teak plantation

Parameter	Plot (100 x 100 m) 1	2	3	4+
Elevation (m)	790	780	770	760
Slope (degree)	13	12	8	12
Stand density (trees/ha)	325	392	338	224
Trees around soil pit	6	6	5	5
Dominant height (dm)	168	189	183	188
Gbh (cm)	81	73	90	87
Site quality	IV	I11	I11	I11
Bulk density (Mg/m^3)	1.42	1.56	1.46	1.54
% Gravel	57	53	59	53
% Sand	30	34	29	35
% Silt	5	5	5	5
% Clay	8	8	7	7
WHC (mm)	261	291	280	290
pH (20:40 water)	5.9	6.0	6.0	5.1
Organic carbon (glkg)	6	6	6	7
Exch acidity (melkg)	13	14	12	15
Exch bases	45	86	55	79

+Four plots only.

Table 6. Site, stand and soil (0-60 cm) parameters in Begur transect of 1960 teak plantation

Parameter	Plot (100 X 100 m) 1	2	3	4	5
Elevation (m)	735	725	725	725	710
Slope (degree)	13	11	11	10	10
Stand density (trees/ha)	367	381	334	323	402
Trees around soil pit	5	5	5	5	5
Dominant height (dm)	163	157	141	138	144
Gbh (cm)	61	69	52	64	64
Site quality	III	III	III	III	III
Bulk density (Mg/m^3)	1.34	1.50	1.45	1.52	1.41
% Gravel	37	33	21	26	20
% Sand	47	51	61	57	61
% Silt	7	8	8	7	8
% Clay	9	8	10	10	11
WHC (mm)	238	301	265	286	264
pH (20:40 water)	5.9	6.3	6.3	6.3	6.3
Organic carbon (g/kg)	8	13	13	12	12
Exch acidity (me/ kg)	16	16	20	18	20
Exch bases (me/kg)	75	93	114	111	101

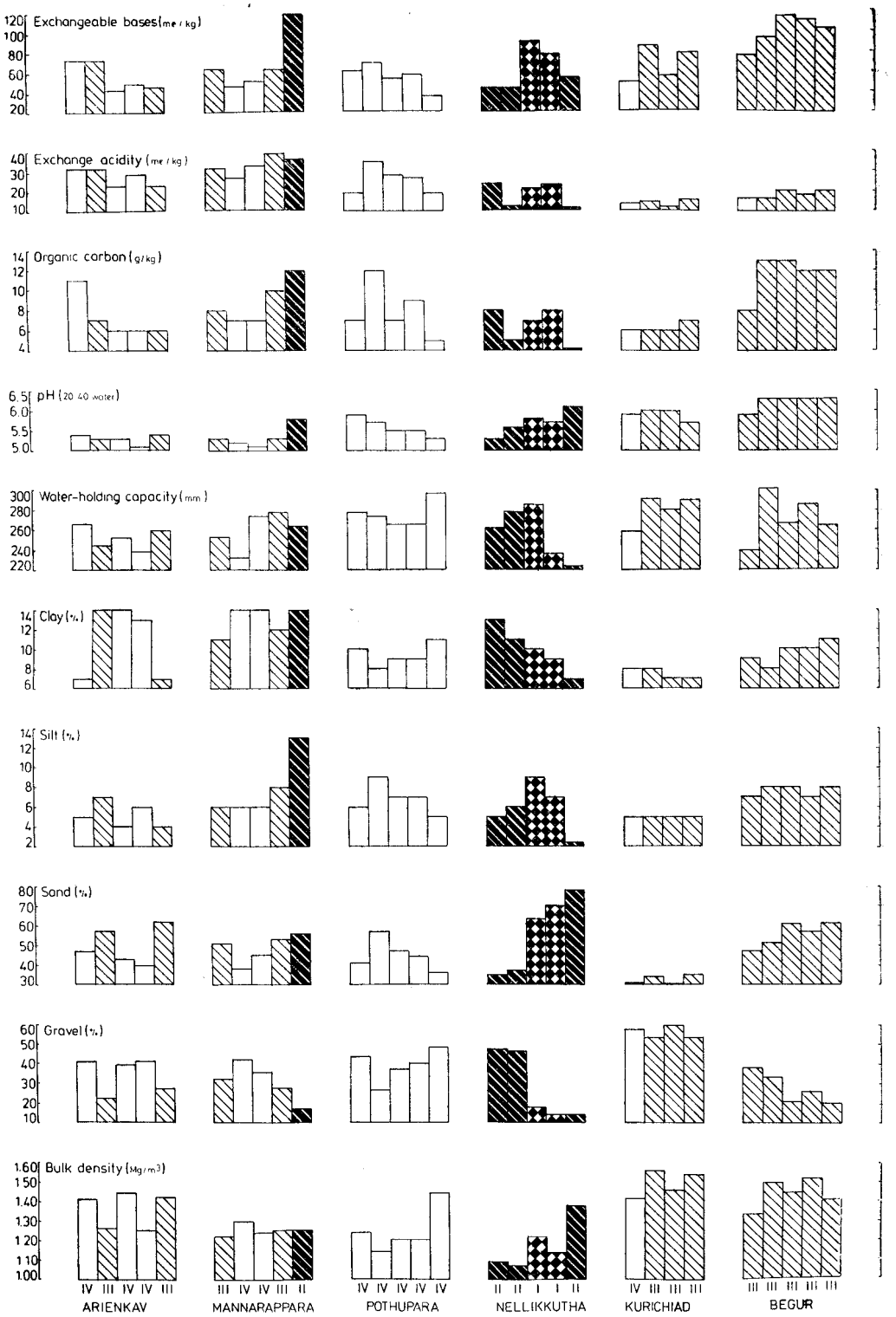

Fig 2 SOIL PARAMETERS IN TEAK PLANTATIONS OF DIFFERENT SITE QUALITY

Table 7. Site, stand and soil (0-20, 20-40 and 40-60 cm) parameter ranges in different teak plantation transects

Parameter	Transect Arienkav	Mannarappara	Pothupara	Nellikkutha	Kurichiad	Begur
Age (yr)	65	53	14	48	43	25
Elevation (m)	180-350	45-90	30-70	70-110	760-790	710-735
Slope (degree)	0-35	0-20	7-16	0-14	8-13	10-13
Dominant height (dm)	140-280	160-310	45-105	230-390	160-210	120-175
Gbh (cm)	86-209	89-241	11-87	80-202	61-104	40-86
Site quality	IV-III	IV-II	IV	11-1	IV-III	III
Bulk density (Mg/m3)	1.16-1.58	1.14-1.42	1.07-1.49	1.06-1.53	1.26-1.75	1.22-1.62
% Gravel	10-56	14-55	11-56	2-60	36-71	9-52
% Sand	36-79	29-62	29-70	23-89	19-46	41-71
% Silt	3-9	4-14	5-11	1-11	3-8	5-10
% Clay	5-19	9-17	7-12	6-13	5-10	8-12
WHC (mm)	72-97	63-101	81-101	64-98	68-109	71-107
pH (20:40 water)	5.0-5.7	5.0-5.8	5.3-5.9	5.2-6.2	5.6-6.1	5.8-6.5
Organic carbon (g/kg)	3-20	3-14	2-18	2-15	2-14	4-20
Exch acidity (me/kg)	15-44	15-47	14-44	7-33	7-21	10-25
Exch bases (me/kg)	22-99	36-136	31-89	28-109	17-134	46-191

Table 8. lntercorrelation between 0-60 cm soil parameters

Parameter	G	S	Si	C	OC	EA
Weighted for gravel						
S	- .961					
Si	- .455	,261				
C	- -154	- .089	.293			
OC	- ,420	.337	.683	- .003		
EA	- .347	.194	.459	.495	.355	
EB	- .510	.452	.669	- .086	.744	.023
Not weighted for gravel						
S	- .585					
Si	.275	- .645				
C	.588	- .912	.275			
OC	.154	- .175	.612	- .I08		
EA	.143	- .422	.256	.393	.266	
EB	.143	- .035	.491	- .220	.565	- .257

G = Gravel, S = sand, Si = silt, C = clay, OC = organic carbon, EA = exchange acidity, EB = exchangeable bases; Coefficients of correlation 0.367 and 0.470 are significant at P = 0.05 and 0.01

Table 9. Comparison of elevation, slope and 0-60 cm soil parameters in eleven age/site quality groups of teak plantations

Group	Age (yr)	Site quality	No. of plots	Soil parameter/significance among groups+
1	48	I	2	Elevation : 4, 5, 9 ds 1, 2, 3, 6, 7, 8, 10, 11; 7, 11 ds 1, 2, 3, 6, 8, 10
2	48	I1	3	Slope : 1 ds 4, 5, 8. 10, 11; 3 ds 8, 1 1 ; 7 ds 11
3	53	I1	1	Bulk density: 2 ds 11; 4 ds 1, 2, 6, 8, 10; 5 ds 1, 2, 3, 6, 7, 8, 10
4	25	111	5	Gravel : 1 ds 2; 5, 9 ds 1 , 2, 3, 4, 6, 7, 8,
5	43	I11	3	10, 11; 8, 11 ds1, 3, 4
6	53	III	2	Sand: lds2,8,10,ll; 5,9dsl,2,3, 4, 6, 7, 8, 11
7	65	III	2	Silt : 1,4 ds 2, 5, 11; 2 ds 6, 8; 3 ds I , 2, 4, 5-11
8	14	IV	5	Clay : nonsignificant
9	43	IV	1	WHC : nonsignificant
10	53	IV	2	pH : 4 ds 8; 6 ds I , 4, 5, 9; 7 ds 4, 5, 9;
11	65	IV	3	10, 11 ds 1-5, 8 , 9
				Organic carbon : 3 ds 2, 5; 4 ds 2, 5, 7-11
				Exchange acidity : I ds 5, 6; 2, 4, 5, 9 ds 3, 6, 7, 8, 10, 11
				Exchangeable bases : 1 ds 2, 8- 11; 2 ds 5; 3, 4 ds 2, 5-11

+Groups differ significantly (ds) at $P = 0.05$ in multiple comparison test.

Elevation, Slope and Site Quality

The six transects come from different physiographic positions and elevation slope differ among the plots (Tables 1-6). Kurichiad and Begur transects

are located in the Wynad plateau (> 700m) and are different from others (Table 9). Among those in lower elevations, Arienkav plots are different from the Mannarappara, Pothupara and Nellikkutha ones. Generally SQ lowers with increase of elevation. Plots have been taken in each transect as far as possible from higher to lower slopes (Tables 1-6). Comparison of differences among the age/SQ groups (Table 9) indicates the effect of slope on SQ. Though its effect is not marked, SQ tends to better with slope decline in the transccts.

Soil Parameters and Site Quality Along the Transects

Site qualities in the Arienkav transect are IV, 111, IV, IV and III (Table 1 and Fig 2). Organic carbon, exchange acidity and exchangeable bases fall, pH remains steady and no clear trends occur for the other variables. With SQ improvement gravel decreases and sand goes up.

Mannarappara transect has SQs III IV, IV, III and I1 (Table 2 and Fig 2). No clear trends exist for soil variables along the transect except that the last plot of SQ I1 has markedly higher levels of silt, pH and exchangeable bases and lower gravel. As SQ betters, gravel declines and sand, silt, pH and exchangeable bases rise.

Site quality is IV in all the plots of Pothupara transect (Table 3 and Fig 2). Along the transect pH decreases and no sharp trends are seen for other parameters.

Nellikkutha transect possesses SQs II II I, I and II (Table 4 and Fig 2). Sand and pH go up whereas gravel and clay diminish along the transect. With SQ improvement, decreases in gravel and increases in sand and exchangeable bases are seen.

There are only four plots in Kurichiad and their SQs are IV, III III and I11 (Table 5 and Fig 2). Bulk density, water-holding capacity and exchangeable bases rise with SQ betterment.

Site quality is III in all the plots of Begur transect (Table 6 and ,Fig 2). Along the transect, gravel decreases and other parameters increase gradually.

Soil Parameters and Site Quality Across the Transects

Analysis of variance of one-way classification of age/SQ groups (Table 9) reveals significant differences among groups in terms of soil parameters. Bulk density, gravel, sand, silt, pH, organic carbon, exchange acidity and exchangeable bases are significantly different in a number of groups; clay and

holding capacity are not. Site quality betters with decrease of gravel both in and across transects. Between sand and gravel an inverse relation exists (Table 8), hence as sand increases SQ improves. In the case of silt, same holds true. Parallel to an increase of pH in a transect, SQ betters but no clear-cut effect is evident across transects. No definite patterns exist for other parameters.

Table 10. Multiple linear regression of top height on soil parameters and age using standardised values

Parameter	Partial regression coefficient
Age	2.415*
Bulk density	- .283*
Gravel	- .550*
Silt	.245^{ns}
Clay	- .180*
WHC	.136^{ns}
pH	- .386^{ns}
Organic carbon	- .140^{ns}
Exch acidity	- .580*
Exch bases	.109^{ns}
F-value of ANOVA= 24.74**	
Coefficient of determination = 0.94** (age: 0.63; soil variables: 0.31)	

*, ** significant at P=0.05 and 0.01 respectively; ns = nonsignificant.

The Kurichiad and Begur transects in the Wynad plateau do not have SQ greater than 111. Here, climatic parameters intrinsic to higher elevations (**>700** m) may be influencing growth of teak. Compared to Arienkav, Mannarappara, Pothupara and Nellikkutha transects in lower elevations, the soils in Kurichiad transect are relatively high in bulk density, gravel, water-holding capacity, pH and exchangeable bases and low in others; that in Begur are high in bulk density, pH, organic carbon and exchangeable bases and low in gravel and exchange acidity.

The effect of soil variables on top height was studied rigorously through multiple linear regression analysis (Table 10). As the stands differed in 'age' it was also included in the model, Soil variables account for 31% of the variation in top height and age 63%. The relative contribution of soil variables in the variation of top height within any age group is around 84%. An examination. of partial regression coefficients points to the prominent effects of gravel, pH and exchange acidity and because of the inverse relationship between gravel and sand (Table 8), the latter will also be an influencing parameter.

CONCLUSION

The variation in SQ along and across Arienkav, Mannarappara, Pothupara, Nellikkutha, Kurichiad and Begur teak plantation transects is explainable in terms of soil parameter gradients. Gravel, sand, pH, exchange acidity and exchangeable bases stand out among the soil parameters influencing SQ. With due weightage for these soil and other relevant site parameters, field attempts to enhance SQ are implicated.

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