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SOIL NUTRIENT MANAGEMENT FOR TEAK PLANTATIONS OF KERALA

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ABSTRACT

A project was undertaken to study the effect of different nutrients N, P, K, Ca and Mg on the growth of teak plantations belonging to different rotations. Study sites were selected in one and two year old (1991 and 1990) third rotation plantations at Aravallikkavu and Valluvasseri in Nilambur range of Nilambur North Forest Division and 11 year old (1981) first and second rotation teak plantations, the former at Pathiri in Chedleth range of South Wynad Forest Division and the latter at Nellikkutha in Vazhikkadavu range of Nilambur North Forest Division. In each site, experimental plots of five hectare were laid out and 15 soil pits, three from each ha, were taken. Samples from 0- 20, 20-40 and 40 -60 cm layers of soil pits were collected. The samples from each layer of the three pits were then pooled into one composite soil sample, resulting in five composite soil pits from each site.

The soils were loam except in the Aravallikkavu plantations where the texture was sandy loam in the surface and 20-40cm layers and loamy sand in the 40-60cm layer. The soils were medium acid in all the layers in the Pathiri, Aravallikavu and Valluvasseri plantations. They were slightly acid in the surface and medium acid in lower layers in the Nellikutha plantation. The site in the Aravallikavu 1991 plantation was highly deteriorated and it was possible to see hard laterites in the surface in certain pockets. Nutrients N, P, K, Ca and Mg, each @ 0, 15, 30 and 45g/tree were added through commercial fertilisers. The fertilisers added were Urea for N. Mussorie rock phosphate for P, Muriate of potash for K, Quick lime for Ca and Magnesium sulphate for Mg.

There were 64 nutrient treatments chosen for the experiment by confounding all three and higher order interactions. These nutrient treatments were laid out in randomised complete block design, which were replicated three times in the one year old (1991) plantation at Aravallikkavu, one and two year old (1991 and 1990) plantations at Valluvasseri and eleven year old (1981) plantation at Pathiri whereas they were replicated two times in the two year old (1990) plantation at Aravallikkavu and 11year

old plantation at Nellikkutha. Each treatment was applied to 10 plants in younger plantations (Aravallikkavu and Valluvasseri) and five trees in older plantations (Nellikkutha and Pathiri).

The study revealed that there was significant difference in increment in height of trees in younger plantations while increment in height, basal area and volume of trees in older plantations showed nonsignificance due to nutrient treatments.

Among the different treatments, comparison among means' test showed that $N_2P_2K_2Ca_2Mg_2$ treatment was found to be the best in younger plantations. This is equivalent to the application of 65g of Urea, 150g of Mussorie rock phosphate, 58g of Muriate of potash, 42g of Quick lime and 149g of Magnesium sulphate/ tree or 163kg of Urea, 375kg of Mussorie rock phosphate, 145kg of Muriate of potash, 105kg of Quick lime and 373kg of Magnesium sulphate/ha. The nutrients have to be added in split doses in the first year during south-west and north-east monsoon periods and double the above amount in split doses in the second and third years during the two monsoon periods. The nonsignificant effect on increment in height in one younger plantation in the,third rotation showed that site evaluation and detailed soil analyses have to be carried out before nutrient recommendation. In other words, nutrient dose is site specific. In order to arrive at the appropriate dose for older plantations, further research is needed.

1. INTRODUCTION

Teak *(Tectona grandis* Linn. f) is the principal forest plantation species in Kerala. The area under teak is around 69,000 ha (KFRI, 1997). Teak is capable of growing over a wide range of edaphic conditions. The quality and distribution of natural teak is related to the nature of the underlying rocks from which the soils are formed while in plantations, among several other factors, the quality will be decided to a large extent by the physical and chemical properties of soils.

In Kerala, out of the total area under teak, 5, 38, 48 and 9% plantations are in site quality classes I, II III and IV, respectively (KFRI, 1997). Among the different teak plantations, majority are in first rotation, some are in second rotation and rest are in third rotation stages. There is a general apprehension that the productivity of teak in pure plantation would fall in successive rotations. This necessiates all efforts to increase the productivity of existing teak plantations.

In a study in first and second rotation teak plantations in Kerala, Jose and Koshy (1972) reported that soil compaction increased with age of plantations. They also observed that the soil fertility declined in older plantations. Similar results of declining soil fertility in successive rotation teak plantations in Kerala were noted by Balagopalan and Jose (1982). In recent years, application of fertilisers has become a common practice in order to ameliorate the soil conditions and enhance the growth. Teak showed better response to fertilisers at the time of planting though many results are not consistent owing to different soil conditions (Kishore, 1987). Prasad *et al* (1986) found that fertiliser application in 10 and 20 year old teak plantations of West Mandla boosted the growth.

At present, in Kerala, fertilisers are added on an arbitrary basis, both in nurseries and plantations which have produced, in a few cases, significant effect on growth, while in most other cases, the effect was not promising. Faster growth of plants under the influence of appropriate fertiliser management may even help to alter the developmental stages of the trees and reduce the rotation period. Hence judicious management of plantations with appropriate dosage of fertilisers is a necessary tool both for proper

utilisation of the added nutrients by the plant as well as for economic benefits. This project was undertaken with the following objectives

1. to study the effect of nutrients on the growth of teak plantations belonging to different rotations
2. to develop a package of practices with nutrient inputs for higher productivity of teak.

2. STUDY AREAS AND METHODS

2.1. Study areas

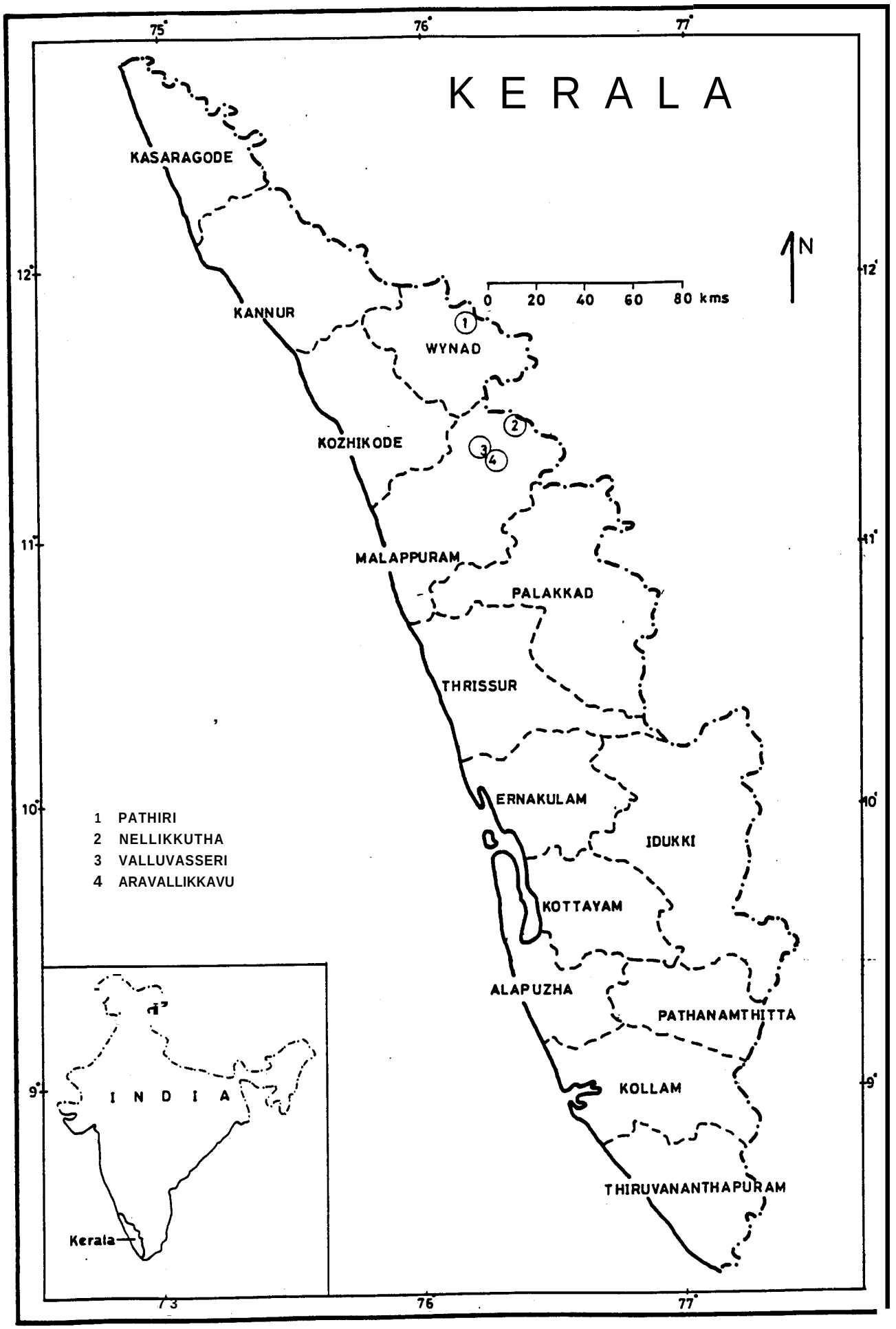
Study areas were selected in first, second and third rotation teak plantations. For first rotation, study area was in South Wynad Forest Division while it was in Nilambur North Forest Division for second and third rotation plantations, respectively.

2.2. Study sites and the soil characteristics

Study sites were selected in one and two year old teak plantations (1991 & 1990) of the third rotation at Aravallikkavu and Valluvasseri in Nilambur range of Nilambur North Forest Division, 11 year old second rotation plantation (1981) at Nellikutha in Vazhikkadvu range of Nilambur North Forest Division and 11 year old first rotation plantation (1981) at Pathiri in Chedleth range of South Wynad Forest Division (Fig. 1). The description of study sites is given in Table 1.

Table 1. Description of study sites

Plantations (sites)	Rotation	Year	Range	Division	No. of trees/ha
Pathiri	I	1981	Chedleth	South Wynad	508
Nellikkutha	II	1981	Vazhikkadavu		493
Aravallikkavu	III	1991	Nilambur	Nilambur (North)	2232
Aravallikkavu	III	1990	Nilambur	Nilambur (North)	2147
Valluvasseri	III	1991	Nilambur	Nilambur (North)	2038
Valluvasseri	III	1990	Nilambur	Nilambur (North)	2003



Fie. 1. Location of study area

In each site, plots of five hectare were demarcated and three soil pits were taken from one hectare. Samples were collected from 0-20, 20-40 and 40-60cm layers of soil pits. The samples from each layer of the three soil pits from one hectare were then pooled into one composite soil sample of each layer, resulting in one pooled soil pit. Thus. there were five composite soil pits from one site.

Analyses were carried out for soil pH, organic carbon, total Nitrogen (N), available Phosphorus (P), Potassium (K), Calcium (Ca) and Magnesium (Mg) as per standard procedures in ASA (1965) and Jackson (1958). Soil texture was also determined. The physical and chemical properties of soils are given in Table 2.

The soils in the Valluvasseri, Nellikkutha and Pathiri plantations were loam in the surface (0-20cm) as well as in deeper layers (20-40 and 40-60cm). They were sandy loam in the surface and 20-40cm layers in the Aravallikkavu teak plantation, while in the 40-60 cm layer, the texture was loamy sand. The soils were medium acid in all the layers in the Aravallikkavu, Valluvasseri and Pathiri plantations. They were slightly acid in the surface and medium acid in lower layers in the Nellikutha plantation.

Organic carbon, total N, available P, K, Ca and Mg contents in soils in the Nellikutha and Pathiri were relatively higher. In the Aravallikkavu and Valluvasseri plantations. the available P contents were below the limit of determination. Exchangeable bases contents were also very low at Aravallikkavu and Valluvasseri.

It was possible to see hard laterites in the surface in certain pockets in the Aravallikkavu 1991 teak plantation and the soils were found to be highly deteriorated.

2.3. Nutrients administered

The nutrients applied were N, P, K, Ca and Mg. They were given each @ 0,15, 30 and 45g/tree. As the nutrients were not able to be administered in elemental form, they were added as commercial fertilisers. The fertilisers added were urea for N, mussorie rock phosphate for P, muriate of potash for K, quick lime for Ca and magnesium sulphate for Mg.

Table 2. Physical and chemical properties of soils in different layers of soil pits in the Aravallikkavu, Valluvasseri, Nellikkutha and Pathiri teak plantation

Sites	Layers (cm)	Properties												
		Sand	Silt	Clay	Textural class	Soil pH	Org. carbon	Exch. Acidity	Exch. bases	Total N	Av. P	Av. K	Av. Ca	Av. Mg
		(……..%. ….)					(%)	(…me/ 100g.. .)		(. …… ppm……)				
Pathiri	0-20	72	12	16	L	5.8	1.90	13	10	1790	6	68	120	72
Nellikkutha	0-20	75	12	13	L	6.1	1.68	11	10	1530	5	55	85	58
Aravallikkavu	0-20	81	8	11	SL	5.7	0.91	9	8	840	2	18	42	30
Valluvasseri	0-20	73	14	13	L	5.8	1.01	8	7	915	2	19	34	31
Pathiri	20-40	70	14	16	L	5.7	1.01	11	9	915	4	30	60	25
Nellikkutha	20-40	72	13	15	L	5.9	0.97	9	8	875	3	22	40	20
Aravallikkavu	20-40	80	10	10	SL	5.7	0.59	7	5	520	-	14	20	12
Valluvasseri	20-40	74	15	11	L	5.8	0.57	6	5	525	-	14	12	9
Pathiri	40-60	69	16	15	L	5.7	0.73	8	7	690	3	18	16	17
Nellikkutha	40-60	70	14	16	L	5.8	0.68	6	6	595	2	12	13	10
Aravallikkavu	40-60	79	12	9	LS	5.6	0.38	4	3	310	-	12	5	9
Valluvasseri	40-60	73	16	11	L	5.7	0.31	4	3	285	-	8	4	8

L - Loam ; SL - Sandy loam; LS - Loamy sand.

2.4. Design of the experiment

As the nutrient treatment combinations were too large in the present experiment, they were reduced by taking a fraction of the complete set of factorial combination. Thus 64 nutrient combinations were chosen for the experiment by confounding all the three and higher order interactions (Table 3). These nutrient treatments were laid out in randomised complete block design, which were replicated three times in the one year old (1991) plantation at Aravallikkavu, one (1991) and two year old (1990) plantations at Valluvasseri and eleven year old (1981) plantation at Pathiri whereas they were replicated two times in the two year old (1990) plantation at Aravallikkavu and 11 year old plantation at Nellikkutha. Each treatment was applied to 10 plants in younger plantations (Aravallikkavu and Valluvasseri) and five trees in older plantations (Nellikkutha and Pathiri).

2.5. Application of fertilisers

Fertilisers were added during north-east monsoon in the first year (1992) in younger plantations around the plants in furrows, 5cm deep and 15cm away from the plant, thoroughly mixed with the soil and then filled with soil. In older plantations, fertilisers were applied in four auger holes, diagonally opposite, dug upto a depth of 40cm, at a distance of 60cm from the tree. Further application of fertilisers were carried out in the second year (1993) with double the dose of that applied in the first year in split doses during south-west and north-east monsoon periods and during south-west monsoon in the third year (1994). The quantity of fertilisers added/ha in the first year in the Aravallikkavu, Valluvasseri, Nellikkutha and Pathiri plantations are shown in Table 4.

2.6. Details of observations taken

The primary observations taken were height (H) in younger plantations and height and girth at breast height (GBH) in older plantations. The measurements were taken at the time of application of the fertilisers in September 1992, after six months (March 1993) and thereafter every twelve months (March 1994, 1995 and 1996).

Table 3. The different nutrient treatments

Trt. No.	Different treatments	Trt. No.	Different treatments	Trt. No.	Different treatments	Trt. No.	Different treatments
1	$N_1P_0K_1Ca_1Mg_1$	17	$N_1P_0K_1Ca_1Mg_3$	33	$N_3P_1K_1Ca_1Mg_1$	49	$N_1P_0K_0Ca_1Mg_1$
2	$N_0P_1K_2Ca_3Mg_1$	18	$N_0P_1K_2Ca_3Mg_3$	34	$N_2P_0K_2Ca_3Mg_1$	50	$N_0P_1K_3Ca_3Mg_1$
3	$N_1P_1K_3Ca_2Mg_0$	19	$N_1P_1K_3Ca_2Mg_2$	35	$N_3P_0K_3Ca_2Mg_0$	51	$N_1P_1K_2Ca_2Mg_0$
4	$N_1P_2K_2Ca_0Mg_3$	20	$N_1P_2K_2Ca_0Mg_1$	36	$N_3P_3K_2Ca_0Mg_3$	52	$N_1P_2K_3Ca_0Mg_3$
5	$N_1P_3K_0Ca_3Mg_2$	21	$N_1P_3K_0Ca_3Mg_0$	37	$N_3P_2K_0Ca_3Mg_2$	53	$N_1P_3K_1Ca_3Mg_2$
6	$N_2P_2K_2Ca_2Mg_2$	22	$N_2P_0K_2Ca_2Mg_0$	38	$N_0P_1K_2Ca_2Mg_2$	54	$N_2P_0K_3Ca_2Mg_2$
7	$N_0P_2K_3Ca_1Mg_2$	23	$N_0P_2K_3Ca_1Mg_0$	39	$N_2P_3K_3Ca_1Mg_2$	55	$N_0P_2K_2Ca_1Mg_2$
8	$N_2P_2K_1Ca_3Mg_0$	24	$N_2P_2K_1Ca_3Mg_2$	40	$N_0P_3K_1Ca_3Mg_0$	56	$N_2P_2K_0Ca_3Mg_0$
9	$N_2P_3K_3Ca_0Mg_1$	25	$N_2P_3K_3Ca_0Mg_3$	41	$N_0P_2K_3Ca_0Mg_1$	57	$N_2P_3K_2Ca_0Mg_1$
10	$N_2P_1K_0Ca_1Mg_3$	26	$N_2P_1K_0Ca_1Mg_1$	42	$N_0P_0K_0Ca_1Mg_3$	58	$N_2P_1K_1Ca_1Mg_3$
11	$N_3P_0K_3Ca_3Mg_3$	27	$N_3P_0K_3Ca_3Mg_1$	43	$N_1P_1K_3Ca_3Mg_3$	59	$N_3P_0K_2Ca_3Mg_3$
12	$N_0P_3K_1Ca_2Mg_1$	28	$N_0P_3K_1Ca_2Mg_1$	44	$N_2P_2K_1Ca_2Mg_3$	60	$N_0P_3K_0Ca_2Mg_3$
13	$N_3P_3K_2Ca_1Mg_0$	29	$N_3P_3K_2Ca_1Mg_2$	45	$N_1P_2K_2Ca_1Mg_0$	61	$N_3P_3K_3Ca_1Mg_0$
14	$N_3P_1K_1Ca_0Mg_2$	30	$N_3P_1K_1Ca_0Mg_0$	46	$N_1P_0K_1Ca_0Mg_2$	62	$N_3P_1K_0Ca_0Mg_2$
15	$N_3P_2K_0Ca_2Mg_1$	31	$N_3P_2K_0Ca_2Mg_3$	47	$N_1P_3K_0Ca_2Mg_1$	63	$N_3P_2K_1Ca_2Mg_1$
16	$N_0P_0Ca_0Mg_0$	32	$N_0P_0Ca_0Mg_2$	48	$N_2P_1K_0Ca_0Mg_2$	64	$N_0P_0K_1Ca_0Mg_0$

Where

N_0,N_1,N_2 and N_3 were Nitrogen; P_o, P_1, P_2 and P_3 were Phosphorus; K_0 K_1, K_2, and K_3 were Potassium; Ca_0, Ca_1, Ca_2, and Ca_3were Calcium ; Mg_0, Mg_1, Mg_2, and Mg_3 were Magnesium each @ 0, 15,30 and 45g/plant.

Table 4. Quantity of fertilisers added (Kg/ha) in different sites

Site	Fertilisers added (kg/ha)														
	Urea			M RP			MOP			Quick lime			Magnesium sulphate		
	N_1	N_2	N_3	P_1	P_2	P_3	K_1	K_2	K_3	Ca_1	Ca_2	Ca_3	Mg_1	Mg_2	Mg_2
Aravallikkavu(1991) (2232 trees)	72.79	145.58	218.37	167.40	334.80	502.20	64.39	128.78	193.17	59.80	119.60	179.40	167.40	344.80	502.20
Aravallikkavu(1990) (2147 trees)	70.01	140.02	210.03	161.03	322.06	483.09	61.94	123.88	185.82	57.52	115.04	172.56	161.03	322.06	483.09
Valluvasseri (1991) (2038 trees)	66.46	132.92	199.38	152.85	305.70	458.55	58.80	117.00	175.50	54.60	109.20	163.80	152.85	305.70	458.55
Valluvasseri (1990) (2003 trees)	65.32	130.64	195.96	150.23	300.46	450.69	57.79	115.58	173.37	53.66	107.32	160.98	150.23	300.46	450.69
Nellikkutha (493 trees)	16.08	32.15	48.23	36.98	73.96	110.94	14.22	28.44	42.66	13.21	26.42	39.63	36.98	73.96	110.94
Pathiri (508 trees)	16.57	33.14	49.71	38.10	76.20	114.30	14.65	29.30	43.95	10.67	21.34	31.01	37.73	75.46	112.19

N_1, N_2, & N_3, were Urea; P_1, P_2, & P_3, were Mussorie rock phosphate (MRP); K_1, K_2& K_3, were Muriate of potash(MOP); Ca_1, Ca_2, & Ca_3, were Quick lime and Mg_1, Mg_2 & Mg_3 were Magnesium sulphate, each @ 15, 30 & 45g/plant.

Basal area (BA) and diameter at breast height (D) were computed. Volume of each tree was estimated using the prediction equation reported by Chaturvedi (1973) which is

$$V = 0.1217 + 0.2257\ D^2H$$

where V = Volume (m^3)

D = Diameter at breast height (m) and H = Tree height (m)

Basal area and volume were computed for each tree in older plantations *viz.*,., Nellikkutha (1981) and Pathiri (1981). Comparison of treatment effectiveness was made separately for height in younger plantations, and basal area and volume in older plantations through analysis of variance, ANOVA (Snedecor and Cochran, 1965). The increment in height, basal area and volume of each tree was computed by subtracting the initial values from the final values. The mean increment among plots receiving different treatments were compared statistically to determine the significance of the difference. The initial growth measurements showed non significance between the treatments in all the plantations. The final growth measurements as well as their increment data were subjected to ANOVA followed by mean comparison test.

Attempts were made to fit the response function using step wise regression to find out the effect of fertiliser inputs on the growth increment.

3. RESULTS AND DISCUSSION

3.1. Effect of nutrients on height of trees in the Aravallikkavu (1991 and 1990) teak plantations

The mean initial height of trees in the one year old (1991) plantation ranged from 0.84m to 2.63m. The mean final height varied from 3.34m in $N_3P_0K_2Ca_3Mg_3$ treatment to 5.20m in $N_0P_2K_3Ca_1Mg_0$ treatment. The mean increment in height was from 2.44 m in control to 2.68m in $N_2P_1K_0Ca_1Mg_3$ treatment (Tables 5 and 15).

In the two year old (1990) plantation; the mean initial height of trees varied from 1.51 m to 3.15m and the variation in mean final height was from 4.28 m in control to 6.58m in $N_0P_2K_3Ca_1Mg_2$ treatment. The mean increment in height differed from 1.45 m in control to 3.59 m in $N_0P_1K_2Ca_3Mg_1$, $N_1P_1K_3Ca_2Mg_0$, $N_1P_0K_0Ca_1Mg_1$, $N_3P_0K_3Ca_3Mg_3$ and $N_2P_2K_2Ca_2Mg_2$ treatments (Tables 6 and 15).

It was observed that there was no significant difference in initial height of trees in the 1991 and 1990 plantations. With respect to final height of trees, the difference was also found to be nonsignificant. The increment in height of trees in the 1991 plantation was found to be nonsignificant due to nutrient treatments while it differed significantly in the 1990 plantation. This could be attributed to the significant influence of nutrients on growth.

Mean comparison test was carried out for the increment in height of tress in the 1990 plantation in order to find out the best nutrient treatment. Out of 64 treatments, the best group consisted of the following six treatments *viz.*,., $N_3P_0K_3Ca_2Mg_0$, $N_0P_1K_2Ca_3Mg_1$, $N_1P_1K_3Ca_2Mg_0$, $N_1P_0K_0Ca_1Mg_1$, $N_3P_0K_3Ca_3Mg_3$ and $N_2P_2K_2Ca_2Mg_2$ and were significantly different from all the others.

Table 5. Mean values of tree height in the Aravallikkavu 1991plantation

Trt. No.	Initial height (m)		Final height (m)		in height (m)	
	mean	sd	mean	sd	mean	sd
1	1.89	0.8836	4.49	0.8208	2.60	0.0693
2	1.82	0.3837	4.37	0.4215	2.55	0.0404
3	1.30	0.6767	3.95	0.5766	2.65	0.1044
4	1.77	0.1779	4.40	0.2107	2.63	0.1050
5	1.52	0.2676	4.12	0.1637	2.60	0.0985
6	1.15	0.3842	3.75	0.3656	2.60	0.0608
7	1.98	0.8041	4.54	0.7308	2.56	0.0757
8	2.62	0.2627	5.18	0.3258	2.56	0.0643
9	1.83	0.7038	4.42	0.7316	2.59	0.0529
10	1.25	0.7522	3.93	0.7305	2.68	0.0351
11	1.38	0.6452	3.96	0.6058	2.58	0.0569
12	1.52	0.4010	4.07	0.3027	2.55	0.1015
13	1.42	1.0661	4.05	0.9962	2.63	0.0929
14	1.78	0.3522	4.37	0.4100	2.59	0.0624
15	1.35	0.8914	3.92	0.9511	2.57	0.0794
16	1.49	0.7932	3.93	0.7094	2.44	0.0819
17	1.33	0.2352	3.88	0.2566	2.55	0.0624
18	1.84	0.5717	4.37	0.5537	2.53	0.1277
19	1.51	0.5173	4.04	0.5811	2.53	0.0950
20	1.53	0.7617	4.09	0.8085	2.56	0.1510
21	1.68	0.7059	4.23	0.6331	2.55	0.0889
22	1.62	0.2902	4.12	0.2194	2.50	0.1353
23	2.63	0.3884	5.20	0.3315	2.57	0.0513
24	1.49	0.4431	3.93	0.4293	2.44	0.0346
25	1.75	0.4300	4.26	0.5105	2.51	0.1102
26	1.40	0.5400	4.02	0.4359	2.62	0.1102
27	1.49	0.3970	4.08	0.3958	2.59	0.0850
28	1.33	0.5252	3.88	0.5910	2.55	0.0643
29	1.70	0.3081	4.23	0.2442	2.53	0.1353
30	1.65	0.3464	4.20	0.2598	2.55	0.0866
31	1.23	0.0529	3.77	0.1250	2.54	0.1217
32	2.06	0.8280	4.60	0.6787	2.54	0.1474

sd - standard deviation

(contd...)

Trt. No. 1 to 32 are the different nutrient treatments

(Table 5 contd...)

Trt. NO.	Initial height (m)		Final height (m)		Increment in height (mj	
	mean	sd	mean	sd	mean	sd
33	1.49	0.9681	3.99	1.0357	2.50	0.1300
34	1.94	0.8372	4.46	0.9464	2.52	0.1387
35	1.36	0.3592	3.93	0.2732	2.57	0.1002
36	1.69	0.7034	4.22	0.7227	2.53	0.0808
37	1.38	0.0289	3.96	0.0513	2.58	0.0751
38	1.35	0.4309	3.95	0.4535	2.60	0.1000
39	1.82	0.6337	4.34	0.6061	2.52	0.0289
40	1.72	0.8554	4.26	0.8652	2.54	0.0153
41	2.05	0.2401	4.60	0.2316	2.55	0.0721
42	1.58	0.7805	4.09	0.7969	2.51	0.0361
43	2.05	0.1868	4.61	0.1401	2.56	0.0529
44	1.66	0.5112	4.20	0.5384	2.54	0.0361
45	2.30	0.5036	4.83	0.5008	2.53	0.0416
46	1.73	0.7263	4.25	0.7104	2.52	0.0643
47	1.81	0.2816	4.31	0.3439	2.50	0.0624
48	1.64	0.6608	4.23	0.6732	2.59	0.1258
49	1.42	0.6413	3.94	0.7519	2.52	0.1106
50	2.24	0.7357	4.77	0.7572	2.53	0.0252
51	2.08	0.5604	4.66	0.5897	2.58	0.0289
52	1.59	0.8400	4.11	0.9158	2.52	0.0814
53	1.95	0.4646	4.51	0.4119	2.56	0.0513
54	1.58	0.2053	4.12	0.1955	2.54	0.0513
55	1.35	1.2304	3.86	1.1750	2.51	0.0764
56	1.31	0.3175	3.85	0.3470	2.54	0.0404
57	2.06	0.4029	4.59	0.3523	2.53	0.0656
58	1.04	0.3601	3.58	0.3753	2.54	0.0777
59	0.84	0.0656	3.34	0.0656	2.50	0.0500
60	1.68	0.6673	4.18	0.71	2.50	0.0500
61	1.54	0.3790	4.08	0.3182	2.54	0.0577
62	1.37	0.5977	3.99	0.5632	2.62	0.0681
63	0.98	0.5601	3.55	0.6353	2.57	0.0751
64	1.26	0.3672	3.79	0.3732	2.53	0.0289

sd- standard deviation

Trt. No. 33 to 64 are the different nutrient treatments

Table 6. Mean values of tree height in the Aravallikkavu 1990 plantation

Trt. No.	Initial height (m)		Final height (m)		Increment in height (m)	
	mean	sd	mean	sd	mean*	sd
1	2.76	1.5698	6.27	1.6476	3.51^{f}	0.0778
2	2.70	0.5657	6.29	0.5445	3.59^{I}	0.0212
3	2.18	0.7778	5.77	0.7566	3.59^{I}	0.0212
4	2.03	0.2475	5.49	0.2546	3.46^{de}	0.0071
5	2.21	0.5798	5.69	0.6152	3.48^{e}	0.0354
6	2.40	0.8839	5.99	0.8697	3.59^{I}	0.0141
7	3.15	1.0889	6.58	1.0253	3.43^{c}	0.0636
8	1.84	0.8980	5.39	0.8273	3.55^{h}	0.0707
9	2.04	0.0849	5.60	0.0283	3.56^{h}	0.1131
10	1.96	0.1768	5.51	0.1061	3.55^{h}	0.0707
11	1.78	0.2192	5.37	0.1909	3.59^{I}	0.0283
12	2.41	0.3394	5.88	0.3465	3.47^{de}	0.0071
13	2.65	0.1697	6.15	0.2546	3.50^{f}	0.0849
14	1.79	0.3677	5.25	0.3960	3.46^{d}	0.0283
15	1.89	0.6505	5.43	0.6010	3.54^{g}	0.0495
16	2.84	0.2616	4.28	0.3536	1.44^{a}	0.0919
17	2.39	0.1626	5.89	0.1131	3.50^{f}	0.0495
18	1.62	0.6364	5.04	0.6576	3.42^{c}	0.0212
19	2.37	0.9687	5.90	0.9899	3.53^{g}	0.0212
20	1.51	0.0849	4.97	0.1909	3.46^{d}	0.1061
21	1.91	0.0566	5.38	0.0071	3.47^{de}	0.0495
22	2.03	1.4920	5.49	1.5698	3.46^{de}	0.0778
23	2.22	0.4031	5.63	0.3889	3.41^{b}	0.0141
24	2.19	0.8697	5.64	0.8980	3.45^{d}	0.0283
25	2.49	0.9405	5.95	1.0253	3.46^{d}	0.0849
26	2.32	0.2333	5.82	0.3041	3.50^{f}	0.0707
27	2.04	0.0919	5.58	0.0707	3.54^{gh}	0.0212
28	2.19	1.6758	5.63	1.5556	3.44^{cd}	0.1202
29	2.12	0.4950	5.63	0.5303	3.51^{f}	0.0354
30	2.32	0.4243	5.80	0.4243	3.48^{e}	2.8428E-08
31	1.59	0.7637	5.03	0.8132	3.44^{c}	0.0495
32	2.07	0.3323	5.46	0.4596	3.39^{b}	0.1273

sd - standard deviation

(contd...)

* - figures superscribed by the same letters do not differ significantly

Trt. No.1 to 32 are the different nutrient treatments

(Table 6 contd..)

Trt. No.	Initial height (m)		Final height (m)		Increment in height (m)	
	mean	sd	mean	sd	mean*	sd
33	1.85	0.4596	5.38	0.5728	3.53^{g}	0.1131
34	1.73	0.2899	5.17	0.1909	3.44^{cd}	0.0990
35	2.77	0.4243	6.35	0.4950	3.58^{I}	0.0707
36	2.28	0.3182	5.77	0.2616	3.49^{ef}	0.0566
37	2.10	0.8132	5.65	0.8485	3.55^{h}	0.0354
38	2.71	1.0960	6.17	1.0607	3.46^{de}	0.0354
39	2.37	1.5556	5.85	1.6263	3.48^{e}	0.0707
40	1.90	0.6081	5.37	0.6576	3.47^{de}	0.0495
41	2.36	0.2263	5.88	0.2475	3.52^{fg}	0.0212
42	2.74	0.2616	6.26	0.2970	3.52^{g}	0.0354
43	1.98	0.3182	5.43	0.2051	3.45^{d}	0.1131
44	1.90	0.1838	5.39	0.2616	3.49^{e}	0.0778
45	1.91	0.6223	5.43	0.7000	3.52^{fg}	0.0778
46	2.75	0.4243	6.29	0.3677	3.54^{gh}	0.0566
47	1.82	0.1202	5.30	0.2828	3.48^{ef}	0.1626
48	3.05	0.0000	6.52	0.1414	3.47^{de}	0.1414
49	2.30	0.0707	5.89	0.1202	3.59^{I}	0.0495
50	2.14	0.7990	5.62	0.8273	3.48^{e}	0.0283
51	2.86	0.3677	6.30	0.4243	3.44^{cd}	0.5660
52	2.29	0.3323	5.82	0.3748	3.53^{g}	0.0424
53	2.39	0.5798	5.85	0.4950	3.46^{d}	0.0849
54	1.93	0.8132	5.37	0.8273	3.44^{d}	0.0141
55	2.62	0.4455	6.13	0.3465	3.51^{f}	0.0990
56	2.52	0.4455	5.97	0.5445	3.45^{d}	0.0990
57	1.70	0.2546	5.16	0.3394	3.46^{d}	0.0849
58	2.20	0.2475	5.72	0.3536	3.52^{g}	0.1061
59	2.02	0.6576	5.54	0.6930	3.52^{g}	0.0354
60	2.41	0.5091	5.94	0.5091	3.53^{s}	1.6398E-05
61	2.18	0.1768	5.68	0.1061	3.50^{f}	0.0707
62	2.15	0.2546	5.71	0.2475	3.56^{h}	0.0071
63	2.09	0.6223	5.56	0.6223	3.47^{de}	0.0000
64	1.57	0.8485	5.05	0.7778	3.48^{e}	0.0707

sd - standard deviation

* figures superscribed by the same letters do not differ significantly

Trt. No. 33to 64 are the different nutrient treatments

3.2. Effect of nutrients on height of trees in the Valluvasseri (1991 and 1990) teak plantations

In the one year old (1991) plantation, the mean initial height of trees varied from 1.17m to 3.08m. The variation in mean final height was from 3.40m in $N_3P_1K_1Ca_0Mg_2$ treatment to 5.39m in $N_0P_0K_0Ca_0Mg_2$ treatment. The height increment was from 2.14m in control to 2.38m in $N_2P_2K_2Ca_2Mg_2$ treatment (Tables 7 and 15).

The mean initial height of trees in the two year old (1990) plantation ranged from 1.84 to 3.82m. It varied from 3.94 m in $N_0P_0K_0Ca_1Mg_3$ to 5.99m in $N_2P_3K_3Ca_0Mg_3$ for the mean final height. The mean increment in height was from 2.00 m in control to 2.25m in $N_2P_2K_2Ca_2Mg_2$ treatment (Tables 8 and 15).

The initial and final height of trees in the 1991 and 1990 plantations indicated that there was no significant difference between nutrient treatments whereas the differences in height increment were significant and could be attributed to the significant influence of nutrient treatments.

3.3. Effect of nutrients on height, basal area and volume of trees in the Nellikkutha (1981) teak plantation

Tables 9,l0 and 11 depict the mean values for initial, final and increment in height, basal area and volume of trees in the 11 year old (1981) Nellikkutha plantation. The results revealed that the initial height ranged from 5.20 m to 12.10m. The final height varied from 6.49m in $N_2P_2K_1Ca_3Mg_3$ treatment to 13.33m in $N_3P_3K_2Ca_1Mg_0$ treatment whereas increment in height was from 1.03m in $N_0P_0K_1Ca_0Mg_0$ treatment to 1.32m in $N_3P_1K_1Ca_1Mg_l$ treatment (Tables 9 and 15).

The initial basal area varied from 26.20cm^2 to 93.55cm^2 while the final one differed from 28.08cm^2 in $N_2P_2K_1Ca_3Mg_2$ treatment to 100.09cm^2 in $N_2P_2K_2Ca_2Mg_2$ treatment. The increment in basal area revealed that there was no increment in the control while the maximum, 8.87cm^2 was in $N_3P_1K_1Ca_1Mg_1$ treatment (Tables 10 and 16).

Table 7. Mean values of tree height in the Valluvasseri 1991 plantation

Trt. No.	nitial height (m)		Final height (m)		increment in height (m)	
	mean	sd	mean	sd	mean*	sd
1	2.29	0.8314	4.57	0.8522	2.28^{e}	0.0208
2	1.43	0.9101	3.69	0.9266	2.26^{de}	0.0458
3	2.08	0.8839	4.30	0.8165	2.22^{bc}	0.1172
4	1.95	0.5069	4.18	0.5299	2.23^{cd}	0.0351
5	2.07	1.3374	4.35	1.4042	2.28^{ef}	0.0954
6	1.78	0.3252	4.16	0.3894	2.38^{h}	0.0666
7	2.03	1.0832	4.29	1.1387	2.26^{de}	0.0557
8	1.40	0.5682	3.57	0.5650	2.17^{a}	0.0635
9	1.86	0.3790	4.15	0.4194	2.29^{f}	0.1222
10	2.59	0.8448	4.78	0.8549	2.19^{b}	0.0929
11	2.97	1.1288	5.16	1.1012	2.19b	0.0306
12	2.68	0.9305	4.95	0.8902	2.27^{de}	0.0907
13	1.60	0.5458	3.80	0.5460	2.20^{b}	0.0751,
14	1.22	0.4186	3.40	0.4335	2.18^{b}	0.0208
15	1.37	0.2371	3.61	0.3274	2.24^{cd}	0.0929
16	2.29	0.3868	4.43	0.4106	2.14^{a}	0.0656
17	2.46	0.9053	4.65	1.0172	2.19^{b}	0.1193
18	1.76	0.7379	4.00	0.7211	2.24^{cd}	0.0231
19	2.32	0.5620	4.58	0.4992	2.26^{de}	0.0651
20	2.08	1.0279	4.33	1.0795	2.25^{de}	0.0666
21	2.12	0.9493	4.40	1.0226	2.28^{f}	0.1007
22	2.96	0.7420	5.21	0.7889	2.25^{de}	0.0503
23	2.42	1.1251	4.62	1.1652	2.20^{b}	0.0404
24	1.61	0.3143	3.87	0.3403	2.26^{de}	0.0513
25	2.55	0.3500	4.74	0.3568	2.19^{b}	0.0173
26	2.17	0.7879	4.42	0.8103	2.25^{de}	0.0231
27	1.70	0.2875	3.95	0.2021	2.25^{d}	0.1353
28	2.73	1.1515	4.98	1.2176	2.25^{d}	0.1044
29	2.18	0.8376	4.43	0.8667	2.25^{de}	0.0321
30	2.54	0.2686	4.79	0.2816	2.25^{de}	0.0153
31	2.61	1.3030	4.91	1.4027	2.30^{fg}	0.1193
32	3.08	1.0496	5.39	1.1566	2.31^{fg}	0.1159

sd - standard deviation (contd...)

* figures superscribed by the same letters do not differ significantly

Trt. No. 1 to 32 are the different nutrient treatments

(Table 7 contd..)

Trt. No.	Initial height (m)		Initial height (m)		Increment in height (m)	
	nean	sd	nean	sd	mean*	sd
33	1.95	1.0866	4.16	1.1877	2.21^{bc}	0.1012
34	1.72	1.2757	3.98	1.2777	2.26^{de}	0.0058
35	2.81	1.2536	5.07	0.3510	2.26^{de}	0.0981
36	2.46	1.8361	4.73	1.9630	2.27^{c}	0.1286
37	2.92	1.7087	5.16	0.7257	2.24^{cd}	0.0529
38	2.29	1.6126	4.58	1.6751	2.29^{f}	0.1015
39	1.89	1.9868	4.15	1.0352	2.26^{de}	0.1 100
40	2.36	1.0970	4.63	1.1581	2.27^{de}	0.0700
41	2.2 1	1.8404	4.44	0.8937	2.23^{cd}	0.0577
42	2.06	1.2155	4.30	1.2934	2.24^{cd}	0.08 14
43	2.69	1.2281	4.93	1.2689	2.24^{cd}	0.0557
44	1.76	3.5582	4.09	0.6183	2.33^{g}	0.065 1
45	2.16	1.3079	4.43	1.3893	2.27^{de}	0.0900
46	2.30	1.1288	4.54	1.2045	2.24^{cd}	0.0802
47	1.90	1.3823	4.2 1	1.3626	2.3l^{fg}	0.0577
48	2.1 1	0.5717	4.40	0.6294	2.29^{f}	0.0577
49	2.06	0.2 178	4.34	0.2 183	2.28^{ef}	0.0954
50	1.40	0.9762	3.68	0.9174	2.28^{ef}	0.0624
51	1.26	0.2444	3.51	0.1652	2.25^{cd}	0.1 159
52	2.12	0.7160	4.40	0.822 1	2.28^{e}	0.1361
53	1.63	0.7130	3.88	0.642 1	2.25^{de}	0.0850
54	1.98	0.476 1	4.26	0.3355	2.28^{ef}	0.1418
55	1.64	0.8205	3.92	0.71 14	2.28^{f}	0.1097
56	1.29	0.4613	3.52	0.3677	2.23^{bc}	0.1079
57	2.03	0.0666	4.29	0.05 13	2.26^{de}	0.0265
58	1.75	0.9200	4.06	0.9 163	2.3 l^{fg}	0.0493
59	1.67	0.09 17	3.93	0.1721	2.26^{de}	0.1002
60	1.55	0.7550	3.82	0.7762	2.27^{de}	0.045 1
61	2.29	1.1628	4.55	1.0577	2.26^{de}	0.1 193
62	2.55	0.9924	4.79	1.0121	2.24^{cd}	0.0872
63	1.17	0.2695	3.45	0.1609	2.28^{e}	0.1242
64	1.77	0.2468	4.02	0.3326	2.25^{de}	0.0896

sd - standard deviation

* - figures superscribed by the same letters do not differ significantly

Trt. No. 33 to 64 are the different nutrient treatments

Table 8. Mean values of tree height in the Valluvasseri 1990 plantation

Trt. No.	Initial height (m)		Final height (m)		Increment in height (m)	
	mean	sd	mean	sd	mean*	sd
1	3.33	0.1750	5.50	0.1250	2.17^{ef}	0.0464
2	1.95	0.3451	4.13	0.3418	2.18^{efg}	0.0473
3	2.33	0.1769	4.44	0.1762	2.11^{bc}	0.0127
4	3.40	1.1852	5.58	1.2003	2.18^{efg}	0.0173
5	2.20	1.0332	4.33	1.1206	2.13^{bc}	0.0901
6	2.93	0.6951	5.18	0.7983	2.25^{h}	0.1100
7	2.88	0.7741	5.03	0.7690	2.15^{d}	0.0433
8	1.87	0.6594	4.00	0.6322	2.13^{cd}	0.0336
9	3.34	0.8778	5.54	0.9059	2.20^{fg}	0.0529
10	2.50	0.5348	4.67	0.5066	2.17^{ef}	0.0314
11	3.06	0.9765	5.23	0.9929	2.17^{def}	0.0144
12	2.31	0.8164	4.42	0.8107	2.11^{b}	0.0236
13	2.58	1.0013	4.74	1.0013	2.16^{ef}	0.0047
14	3.05	1.0150	5.23	0.9903	2.18^{ef}	0.0323
15	1.98	1.4500	4.22	1.4027	2.24^{h}	0.0979
16	2.76	1.4781	4.76	1.4537	2.00^{a}	0.0315
17	2.10	0.9236	4.26	0.9686	2.16^{de}	0.0450
18	2.44	0.8723	4.59	0.8790	2.15^{cd}	0.0277
19	1.84	0.6506	3.95	0.6437	2.11^{bc}	0.0312
20	3.13	1.3012	5.28	1.2885	2.15^{de}	0.0127
21	2.71	0.8559	4.83	0.8386	2.12^{bc}	0.0173
22	3.57	0.7448	5.77	0.7408	2.20^{fg}	0.0250
23	2.48	1.5903	4.64	1.5195	2.16^{de}	0.0819
24	2.41	1.1889	4.52	1.1780	2.11^{bc}	0.0260
25	3.82	0.4497	5.99	0.4366	2.17^{ef}	0.0433
26	3.08	0.8765	5.23	0.9114	2.15^{cd}	0.0629
27	3.16	0.2065	5.33	0.1852	2.17^{ef}	0.0250
28	2.46	0.9400	4.57	0.8607	2.11^{b}	0.0803
29	2.01	1.0393	4.16	0.9725	2.15^{d}	0.0791
30	2.52	0.2931	4.64	0.3386	2.12^{bc}	0.0661
31	3.03	0.5782	5.20	0.5811	2.17^{ef}	0.0254
32	3.33	1.3066	5.48	1.3481	2.15^{cd}	0.0629

sd - standard deviation (contd..)

* - figures superscribed by the same letters do not differ significantly

Trt. No. 1 to 32 are the different nutrient treatments

Table 8 contd...)

Trt. No.	Initial height (m)		Final height (m)		increment in height (m)	
	mean	sd	mean	sd	mean*	sd
33	2.72	1.0861	4.87	1.0942	2.15^{cd}	0.0144
34	2.98	0.1852	5.16	0.1682	2.18^{ef}	0.0459
35	2.20	0.5605	4.38	0.5605	2.18^{ef}	0.0000
36	2.33	0.2779	4.55	0.2857	2.22^{gh}	0.0192
37	2.61	0.8376	4.76	0.8466	2.15^{de}	0.0267
38	1.93	0.1986	4.08	0.2007	2.15^{cd}	0.0168
39	3.21	0.2759	5.34	0.2511	2.13^{cd}	0.0375
40	3.21	0.5368	5.40	0.4611	2.19^{fg}	0.0763
41	1.89	0.7454	4.02	0.7702	2.13^{bc}	0.0250
42	1.85	0.3247	3.94	0.3502	2.09^{b}	0.0260
43	3.03	1.1336	5.16	1.1587	2.13^{cd}	0.0288
44	3.02	0.9872	5.20	1.0401	2.18^{efg}	0.0756
45	2.08	1.2555	4.26	1.3002	2.18^{ef}	0.0480
46	3.30	1.621	5.49	1.6084	2.19^{fg}	0.0712
47	2.49	1.7002	4.62	1.7163	2.13^{cd}	0.0381
48	2.11	0.2254	4.26	0.2658	2.15^{de}	0.0500
49	3.45	0.3573	5.64	0.3704	2.19^{fg}	0.0144
50	2.62	0.1617	4.76	0.2352	2.14^{cd}	0.0851
51	3.17	0.7617	5.36	0.7744	2.19^{efg}	0.0173
52	3.59	0.6223	5.73	0.6062	2.14^{cd}	0.0144
53	2.94	0.5717	5.11	0.5289	2.17^{def}	0.0520
54	2.95	0.6767	5.13	0.6473	2.18^{ef}	0.0250
55	2.74	0.692	4.92	0.7414	2.18^{ef}	0.0542
56	2.68	0.8952	4.81	0.8989	2.13^{bc}	0.0250
57	3.03	0.3553	5.21	0.3418	2.18^{ef}	0.0250
58	3.20	0.3215	5.36	0.3568	2.16^{de}	0.0375
59	2.36	1.3273	4.54	1.2786	2.18^{efg}	0.0520
60	2.91	0.3894	5.08	0.4119	2.17^{def}	0.0381
61	3.05	0.1868	5.19	0.2506	2.14^{cd}	0.0629
62	3.20	0.3288	5.38	0.3060	2.18^{efg}	0.0601
63	2.93	0.5155	5.07	0.5048	2.14^{cd}	0.0127
64	2.49	0.7093	4.61	0.7192	2.12^{bc}	0.0072

sd - standard deviation

* - figures superscribed by the same letters do not differ significantly

Trt. No. 33 to 64 are the different nutrient treatments

Table 9 . Mean values of tree height in the Nellikkutha 1981 plantation

Trt. No.	nitial height (m)		Final height (m)		ncrement in height (m)	
	mean	sd	mean	sd	mean	sd
1	9.49	0.9122	ı0.59	0.8344	1.10	0.0849
2	1.10	2.7082	12.34	2.9204	1.24	0.2121
3	8.45	0.4455	9.53	0.5728	1.08	0.1273
4	6.84	0.9546	7.98	1.0960	1.14	0.1414
5	0.89	3.7123	12.09	3.8749	1.20	0.1626
6	0.94	0.7920	12.13	0.8839	1.19	0.0919
7	8.91	0.3889	9.99	0.4384		0.0566
8	10.69	3.2668	11.88	3.3588	1.19	0.0919
9	10.29	2.8850	11.45.	3.0052	1.16	0.1131
10	10.35	0.9192	11.52	0.6859	1.17	0.2263
11	6.37	2.1567	7.57	1.9799	1.20	0.1626
12	7.80	0.5940	9.01	0.5515	1.21	0.0495
13	12.10	4.8295	13.33	4.9427	1.23	0.1061
14	7.85	1.8880	9.03	1.8455	1.18	0.0424
15	8.88	2.2981	9.94	2.2062	1.06	0.0849
16	8.83	1.4142	9.90	1.4142	1.07	0.0000
17	10.17	0.7071	11.29	0.5445	1.12	0.1626
18	8.02	1.6263	9.20	1.5556	1.18	0.0707
19	7.79	0.7637	9.02	0.7283	1.23	0.0354
20	7.35	2.3335	8.60	2.2627	1.25	0.0707
21	10.03	1.2092	11.08	1.2021	1.05	0.0141
22	9.11	0.3182	10.39	0.4031	1.28	0.0707
23	10.42	0.1202	11.59	0.1202	1.17	0.0000
24	5.20	2.7860	6.49	2.6022	1.29	0.1838
25	9.92	0.1202	11.15	0.1131	1.23	0.0000
26	10.19	0.4384	11.35	0.4950	1.16	0.0566
27	9.25	0.5233	10.49	0.6505	1.24	0.1202
28	8.82	0.0919	10.02	0.0707	1.20	0.0212
29	9.94	0.7920	11.04	0.9334	1.10	0.1414
30	9.24	3.0264	10.37	2.9698	1.13	0.0495
31	9.79	1.3576	10.89	1.2940	1.10	0.0566
32	9.25	1.0607	10.38	1.0607	1.13	0.0000

sd - standard deviation

(contd...)

Trt. No. 1 to 32 are the different nutrient treatments

Table 9 contd..)

Trt. No.	Initial height (m)		Final height (m)		Increment in height(m)	
	mean	sd	mean	sd	mean	sd
33	7.50	0.4667	8.82	0.3536	1.32	0.1202
34	8.13	0.1768	9.30	0.1838	1.17	0.0071
35	7.53	3.3305	8.81	3.1678	1.28	0.1556
36	8.90	0.3182	10.00	0.2828	1.10	0.0424
37	7.78	1.4496	8.96	1.4284	1.18	0.0141
38	7.74	1.0819	8.89	1.0112	1.15	0.0707
39	7.92	0.5860	9.05	0.5900	1.13	0.0000
40	9.36	0.6718	10.52	0.7778	1.16	0.0919
41	8.06	3.0971	9.18	2.9345	1.12	0.1626
42	8.75	1.5981	9.92	1.5768	1.17	0.0212
43	7.01	0.9334	8.28	1.0253	1.27	0.0919
44	10.06	0.4455	11.18	0.5020	1.12	0.0566
45	9.81	1.6829	10.88	1.5910	1.07	0.0849
46	6.84	1.3576	8.03	1.3364	1.19	0.0141
47	7.61	1.8031	8.74	1.9304	1.13	0.1414
48	7.32	0.4172	8.56	0.3677	1.24	0.0495
49	9.44	0.4455	10.53	0.5728	1.09	0.1273
50	9.19	0.9758	10.26	0.8839	1.07	0.0919
51	9.86	1.4496	10.96	1.3081	1.10	0.1414
52	10.07	0.2616	11.19	0.2687	1.12	0.0000
53	9.28	2.2698	10.42	2.1425	1.14	0.1273
54	7.53	0.3182	8.72	0.3536	1.19	0.0424
55	10.69	0.0919	11.83	0.0707	1.14	0.0212
56	8.75	0.1131	9.95	0.0707	1.20	0.0424
57	11.00	3.0688	12.07	3.0193	1.07	0.0495
58	10.86	0.7425	11.99	0.6505	1.13	0.0919
59	9.84	0.2333	10.90	0.1414	1.06	0.0919
60	8.82	1.3223	10.00	1.3152	1.18	0.0141
61	10.03	0.2051	11.15	0.0707	1.12	0.1414
62	8.10	2.1496	9.20	2.0082	1.10	0.1414
63	8.67	1.1809	9.90	1.0324	1.23	0.1414
64	10.19	0.2687	11.22	0.3041	1.03	0.0354

sd - standard deviation

Trt. No. 33 to 64 are the different nutrient treatments

Table 10. Mean values of basal. area of trees in the Nellikkutha 1981 plantation

Trt. No	Initial basal area (cm^2)		Final basal area (cm^2)		Increment in basal area- (cm^2)	
	mean	sd	mean	sd	mean	sd
1	66.66	21.8637	71.66	26.4317	5.00	4.5467
2	48.23	3.5355	49.88	5.8690	1.65	2.3264
3	56.32	26.8913	59.68	31.6430	3.36	4.7518
4	43.94	4.7942	46.99	2.9204	3.05	1.8809
5	56.85	7.7075	59.15	9.1570	2.30	1.4637
6	93.55	25.3851	00.09	22.9244	6.54	2.4607
7	41.34	25.3639	41.89	26.1488	0.55	0.7707
8	50.89	4.0517	52.32	5.1831	1.43	1.1384
9	67.43	14.8563	68.95	15.2452	1.52	0.3748
10	71.22	41.6981	76.82	47.3549	5.60	5.6569
11	32.46	21.7435	33.43	23.1153	0.97	1.3789
12	44.45	17.0130	45.71	17.8049	1.26	0.8061
13	72.95	11.7097	76.66	13.3077	3.71	1.5981
14	39.47	32.3289	41.73	33.9411	2.26	122
15	65.80	42.9567	70.52	44.1022	4.73	1.1667
16	37.55	0.9617	37.55	0.9617	0.00	0.0000
17	72.25	7.1842	76.27	8.0115	4.02	0.8415
18	73.19	9.6379	78.50	11.0309	5.31	1.4213
19	47.56	29.0055	49.29	30.6036	1.73	1.6051
20	51.35	7.0004	55.37	8.2944	4.02	1.2799
21	53.64	3.4507	56.10	6.9296	2.46	3.4860
22	58.82	20.5768	62.73	21.7435	3.91	1.1809
23	72.98	9.1217	79.15	12.6148	6.17	3.5002
24	26.20	26.9761	28.08	29.4439	1.88	2.4678
25	74.29	19.3535	79.18	18.3141	4.89	1.0394
26	78.19	18.4908	83.82	16.0018	5.63	2.4890
27	45.16	11.9147	46.17	13.3431	1.01	1.4284
28	46.06	7.2691	47.60	5.0912	1.54	2.1779
29	74.53	27.4428	76.70	30.5117	2.17	3.0618
30	69.02	31.6572	74.86	31.1481	5.84	0.5233
31	45.72	0.6859	46.35	0.2121	0.63	0.9122
32	52.94	26.071	54.84	28.7580	1.90	2.6941

sd- standard deviation (contd...)

Trt. No. 1 to 32 are the different nutrient treatments

Trt. No.	Initial basal area (cm^2)		Final basal area (cm^2)		Increment in basal area (cm^2)	
	mean	Sd	mean	sd	mean	sd
33	60.40	30.0238	69.25	40.1354	8.85	10.1046
34	41.30	24.8619	43.63	25.9862	2.33	1.1455
35	46.80	36.8473	49.70	37.8373	2.90	0.9899
36	38.26	2.3688	38.84	1.5415	0.58	0.8344
37	52.28	24.3598	55.26	26.3609	2.98	1.9940
38	50.71	8.6126	53.40	8.5843	2.69	0.0212
39	55.53	29.2742	58.04	32.0107	2.51	2.7577
40	72.09	6.9084	79.69	1.1102	7.60	5.7912
41	45.33	12.7279	48.74	14.8987	3.41	2.1991
42	54.07	43.8618	56.85	47.0297	2.78	3.1608
43	38.33	16.3695	39.46	17.5504	1.13	1.1738
44	69.94	31.7986	72.56	35.5109	2.62	3.7052
45	67.29	24.3386	73.20	23.1507	5.91	1.1879
46	32.02	2.7789	34.07	5.6781	2.05	2.8991
47	48.69	14.1633	52.86	11.3986	4.17	2.7648
48	42.19	9.5601	47.64	12.1127	5.45	2.5527
49	63.16	2.3688	67.28	4.2780	4.12	1.9021
50	46.72	3.4648	47.62	4.7376	0.90	1.2587
51	54.27	3.3022	57.74	8.2166	3.47	4.9073
52	77.81	17.4797	84.25	16.0230	6.44	1.4425
53	51.62	5.4942	55.27	6.1306	3.65	0.6435
54	52.98	0.4596	57.78	1.0960	4.80	1.5698
55	68.31	22.1466	72.71	23.0375	4.40	0.8768
56	51.74	16.6382	53.87	16.0725	2.13	0.5798
57	83.45	45.4670	90.54	52.9835	7.09	7.5095
58	74.71	8.2378	81.65	3.4648	6.94	4.7942
59	77.40	34.3654	81.09	36.0766	3.69	1.7607
60	54.02	14.8705	57.21	15.1179	3.19	0.2616
61	67.28	1.4213	73.11	0.3677	5.83	1.7819
62	48.40	32.9865	50.64	35.1220	2.24	2.1496
63	57.86	38.7141	60.66	40.5455	2.80	1.8314
64	73.23	29.3096	77.19	32.4067	3.96	3.1113

sd - standard deviation

Trt. No. 33 to 64 are the different nutrient treatments

The mean values for initial minimum and maximum volume of trees were $12.83x10^{-2}m^3$ and $15.53 \times 10^{-2}m^3$. The mean final values were between $12.96 \times 10^{-2}m^3$ in $N_2P_2K_1Ca_3Mg_2$ and $16.17 \times 10^{-2}m^3$ in $N_2P_2K_2Ca_2Mg_2$ treatments. The increment in volume varied from $0.1200 \times 10^{-2}m^3$ to $0.6350 \times 10^{-2}m^3$ in control and $N_2P_2K_2Ca_2Mg_2$ treatment, respectively (Tables 11 and 17). The initial as well as final height, basal area and volume and their increments showed that there was no significant difference due to the application of nutrients.

3.4. Effect of nutrients on height, basal area and volume of trees in the Pathiri (1981) teak plantation

The initial mean values for minimum and maximum height of trees were 8.22m and 13.44m. The corresponding final values were 8.48m and 13.77m in $N_1P_3K_0Ca_2Mg_1$ and $N_3P_3K_3Ca_1Mg_0$ treatments, respectively. The increment in height ranged from 0.25m in $N_0P_2K_3Ca_0Mg_1$ to 0.38m in $N_2P_3K_3Ca_1Mg_2$ treatments (Tables 12 and 15).

The mean initial basal area values were between $158.27cm^2$ and $319.63cm^2$. The final values varied from $158.97cm^2$ in $N_2P_1K_0Ca_0Mg_0$ to $320.80cm^2$ in $N_3P_3K_3Ca_1Mg_0$ treatments. The increment was from $0.70cm^2$ in $N_2P_1K_0Ca_0Mg_0$ to $2.87cm^2$ in $N_0P_2K_3Ca_1Mg_2$ treatments (Tables 13 and 16).

The initial minimum volume of trees was $17.19 \times 10^{-2}m^3$ and the maximum was $25.54 \times 10^{-2}m^3$. The final volume varied from $17.37 \times 10^{-2}m^3$ in $N_0P_0K_0Ca_0Mg_2$ and $N_1P_3K_0Ca_2Mg_1$ treatments to $25.86 \times l0^{-2}\ m^3$ in $N_3P_3K_3Ca_1Mg_0$ treatment. The increment in volume varied from $0.1500 \times 10^{-2}m^3$ in $N_2P_1K_0Ca_0Mg_0$ to $0.4400 \times l0^{-2}\ m^3$ in $N_2P_2K_1Ca_3Mg_0$ treatments (Tables 14 and 17). The initial, final and increment with respect to height, basal area and volume showed that there was no significant difference between treatments.

Table 11. Mean values of volume of trees at Nellikkutha 1981 plantation

Trt. No.	Initial volume (m3)		Final Volume (m3)		Increment in Volume (m3)	
	mean x 10^{-2}	sd	mean x 10^{-2}	sd	mean x 10^{-2}	sd
1	14.0900	0.007212	14.4600	0.009192	0.3700	0.001980
2	13.7250	0.002758	13.9500	0.002121	0.2250	0.000636
3	13.7950	0.009122	14.0700	0.011455	0.2750	0.002333
4	13.3200	0.001980	13.5550	0.001485	0.2350	0.000495
5	13.9700	0.003111	14.2300	0.002828	0.2600	0.000283
6	15.5300	0.000849	16.1650	0.000778	0.6350	0.001626
7	13.2300	0.005657	13.3700	0.006647	0.1400	0.000990
8	13.8500	0.006930	14.0750	0.007707	0.2250	0.000778
9	14.2900	0.010324	14.5800	0.011314	0.2900	0.000990
10	14.4950	0.012940	14.9100	0.015839	0.4150	0.002899
11	12.9250	0.006435	13.0550	0.007425	0.1300	0.000990
12	13.3850	0.007283	13.5750	0.007990	0.1900	0.000707
13	14.9400	0.002263	15.3250	0.002192	0.3850	0.000071
14	13.2550	0.009829	13.4500	0.011455	0.1950	0.001626
15	14.2000	0.013576	14.5600	0.014991	0.3600	0.001414
16	13.1900	0.001414	13.3100	0.001414	0.1200	5.95E-12
17	14.4750	0.003041	14.8350	0.003748	0.3600	0.000707
18	14.7800	0.007495	15.1950	0.008556	0.4150	0.001061
19	13.5500	0.011172	13.7550	0.012516	0.2050	0.001344
20	13.7300	0.000990	14.0200	0.001838	0.2900	0.000849
21	13.7250	0.002899	13.9800	0.004243	0.2550	0.001344
22	13.9700	0.004808	14.3050	0.006010	0.3350	0.001202
23	14.5350	0.004455	15.0050	0.006152	0.4700	0.001697
24	12.8250	0.007990	12.9600	0.009475	0.1350	0.001485
25	14.5250	0.006718	14.9600	0.006930	0.4350	0.000212
26	14.6050	0.004879	15.0600	0.004808	0.4550	0.000071
27	13.4350	0.003323	13.6100	0.003960	0.1750	0.000636
28	13.4150	0.001061	13.6150	0.000636	0.2000	0.000424
29	14.5150	0.011950	14.8200	0.014001	0.3050	0.002051
30	14.3300	0.012021	14.7450	0.012940	0.4150	0.000919
31	13.4800	0.001838	13.6500	0.002121	0.1700	0.000283
32	13.7000	0.007637	13.9350	0.009546	0.2350	0.001909

sd - standard deviation

(contd..)

Trt. No. 1 to 32 are the different nutrient treatments

(Table 11 contd..)

Trt. No.	Initial Volume (m3)		Final Volume (m3)		Increment in Volume (m3)	
	mean x 10^{-2}	sd	mean x 10^{-2}	sd	mean x 10^{-2}	sd
33	14.2250	0.014354	14.8050	0.020011	0.5800	0.005657
34	13.2650	0.007000	13.4650	0.008273	0.2000	0.001273
35	13.5650	0.012092	13.8050	0.013647	0.2400	0.001556
36	13.1950	0.000212	13.3250	0.000354	0.1300	0.000141
37	13.6850	0.008556	13.940	0.010041	0.2550	0.001485
38	13.7050	0.004313	13.9450	0.004455	0.2400	0.000141
39	13.0825	0.011102	14.0700	0.012869	0.2450	0.001768
40	14.2950	0.000919	14.7950	0.000636	0.5000	0.001556
41	13.4500	0.005374	13.7000	0.006505	0.2500	0.001131
42	13.7700	0.015274	14.0350	0.017748	0.2650	0.002475
43	13.2400	0.006081	13.4100	0.007212	0.1700	0.001131
44	14.3550	0.012092	14.6650	0.014496	0.3100	0.002404
45	14.3150	0.010394	14.7150	0.010677	0.4000	0.000283
46	12.9750	0.002616	13.1500	0.003818	0.1750	0.001202
47	13.4800	0.003677	13.7650	0.003465	0.2850	0.000212
48	13.4250	0.003748	13.7550	0.004738	0.3300	0.000990
49	14.1200	0.002687	14.4650	0.003748	0.3450	0.001061
50	13.4600	1.3426E-09	13.6300	0.000566	0.1700	0.000566
51	13.8100	0.004243	14.1250	0.006152	0.3150	0.001909
52	14.6950'	0.002192	15.1800	0.001980	0.4850	0.000212
53	13.7600	0.002970	14.0500	0.003677	0.2900	0.000707
54	13.6850	0.000636	14.0050	0.000212	0.3200	0.000424
55	14.3950	0.007142	14.7700	0.007920	0.3750	0.000778
56	13.5150	0.003748	13.7600	0.004101	0.2450	0.000354
57	15.0600	0.021072	15.5950	0.025668	0.5350	0.004596
58	14.5900	0.000000	15.1100	0.001838	0.5200	0.001838
59	14.8700	0.015839	15.2300	0.017536	0.3600	0.001697
60	13.8100	0.002828	14.0850	0.003182	0.2750	0.000354
61	14.3250	0.000778	14.7600	0.001414	0.4350	0.000636
62	13.5200	0.009617	13.7300	0.011314	0.2100	0.001697
63	13.9250	0.012374	14.2100	0.014001	0.2850	0.001626
64	14.4300	0.009899	14.7900	0.011879	0.3600	0.001980

sd - standard deviation

Trt. No. 33 to 64 are the different nutrient treatments

Table 12. Mean values of tree height at Pathiri 1981 plantation

Trt. No.	Initial height (m)		Final height (m)		lncrement in height (m)	
	mean	Sd	mean	sd	mean	sd
1	9.08	1.3378	9.40	1.3412	0.32	0.0289
2	10.44	0.1963	0.77	0.2000	0.33	0.1015
3	10.05	1.1809	0.39	1.1846	0.34	0.0850
4	10.36	1.8738	0.68	1.9416	0.32	0.0764
5	10.64	0.8493	0.93	0.8721	0.29	0.0173
6	10.33	2.5166	0.64	2.6020	0.31	0.0854
7	10.75	1.7252	1.07	1.6967	0.32	0.0404
8	11.36	2.9329	1.71	3.0427	0.35	0.1079
9	11.39	1.6677	1.68	1.6671	0.29	0.0115
10	12.25	1.7252	2.53	1.7390	0.28	0.0153
11	9.47	0.7068	9.81	0.6295	0.34	0.0814
12	10.32	1.5058	0.66	1.6318	0.34	0.1401
13	12.00	0.3300	2.33	0.3350	0.33	0.0577
14	10.36	0.6255	0.66	0.6170	0.30	0.0300
15	11.18	0.8350	1.44	0.8501	0.26	0.0173
16	10.89	1.0180	1.23	1.0083	0.34	0.0656
17	10.97	1.4747	1.27	1.4747	0.30	5.2154E-09
18	9.01	2.5166	9.29	2.5325	0.28	0.0173
19	10.82	2.0505	1.09	2.0714	0.27	0.0513
20	10.29	2.7408	0.60	2.7663	0.31	0.0681
21	11.86	1.3309	2.18	1.2840	0.32	0.0473
22	9.25	0.4330	9.52	0.4053	0.27	0.0361
23	11.00	0.3300	1.30	0.3300	0.30	5.2154E-09
24	10.90	1.8973	1.17	1.8985	0.27	0.0153
25	10.97	0.5557	1.29	0.6030	0.32	0.0723
26	9.78	2.1444	0.08	2.1134	0.30	0.0300
27	10.58	0.6479	0.89	0.6428	0.31	0.0173
28	8.70	2.0401	9.01	2.0761	0.31	0.0569
29	10.39	2.5494	0.67	2.5550	0.28	0.0173
30	8.50	2.1794	8.84	2.1480	0.34	0.0608
31	10.03	4.0896	0.34	4.1457	0.31	0.1102
32	8.89	2.4589	9.18	2.4644	0.29	0.0173

sd - standard deviation

(contd...

Trt. No. 1 to 32 are the different nutrient treatments

(Table 12 contd...)

Trt. No.	Initial height (m)		Final height (m)		Increment in height (m)	
	mean	sd	mean	sd	mean	sd
33	0.31	1.9012	0.61	1.9012	0.30	5.2154E-09
34	9.17	1.6438	9.43	1.6713	0.26	0.0351
35	0.78	1.3489	1.09	1.3626	0.31	0.0173
36	1.53	1.5410	11.81	1.5448	0.28	0.0153
37	9.69	0.3386	10.00	0.3315	0.31	0.0404
38	9.67	1.4534	9.93	1.4799	0.26	0.0351
39	9.08	1.1815	9.47	1.0999	0.39	0.0850
40	10.00	1.6700	10.33	1.5660	0.33	0.1155
41	8.68	0.5635	8.930	0.5862	0.25	0.0436
42	10.37	1.5151	10.70	1.5223	0.33	0.0462
43	9.78	2.6720	10.09	2.6346	0.31	0.0513
44	11.14	1.6989	11.41	1.6629	0.27	0.0361
45	9.92	1.0104	10.20	0.9959	0.28	0.0153
46	8.83	2.3124	9.16	2.2451	0.33	0.0681
47	8.22	2.2223	8.48	2.2433	0.26	0.0513
48	10.11	2.2180	10.37	2.2605	0.26	0.0513
49	12.11	0.8404	12.40	0.8298	0.29	0.0115
50	8.97	2.6372	9.23	2.6762	0.26	0.0529
51	10.92	3.2756	11.23	3.2956	0.31	0.0723
52	9.83	0.7638	10.13	0.8327	0.30	0.1000
53	9.83	0.7638	10.12	0.7715	0.29	0.0153
54	11.78	0.508:	12.06	0.5056	0.28	0.0173
55	9.72	1.4548	9.99	1.4714	0.27	0.0361
56	9.80	1.2931	10.12	1.2703	0.32	0.0173
57	10.50	2.5981	10.78	2.6010	0.28	0.0153
58	10.42	0.7936	10.72	0.7816	0.30	0.0300
59	9.67	1.3769	9.99	1.4171	0.32	0.0462
60	10.64	0.6255	10.93	0.6158	0.29	0.0115
61	13.44	2.6921	13.77	2.6312	0.33	0.0681
62	9.97	2.382	10.29	2.4090	0.32	0.0473
63	11.78	1.338’	12.08	1.3387	0.30	
64	10.69	2.652:	11.02	2.6043	0.33	0.1266

sd - standard deviation

Trt. No. 33 to 64 are the different nutrient treatments

Table 13. Mean values of basal area of trees at Pathiri 1981 plantation

Trt. No.	Initial basal area (cm^2)		Final basal area (cm^2)		Increment in basal area (cm^2)	
	mean	sd	mean	sd	mean	sd
1	215.03	19.0857	216.17	19.2095	1.14	0.5346
2	244.37	80.2519	246.73	81.7817	2.36	1.5087
3	170.80	15.6809	171.77	16.0594	0.97	0.3727
4	170.40	55.3220	171.83	55.4008	1.43	1.2741
5	226.73	56.9066	228.03	56.4431	1.30	0.6379
6	233.13	90.9940	234.90	92.4169	1.77	1.7183
7	259.10	63.6590	261.97	64.5316	2.87	1.9853
8	279.63	29.5761	282.40	30.9858	2.77	1.9258
9	241.87	68.0545	244.17	69.6042	2.30	1.5658
10	295.27	31.8021	296.97	31.6320	1.70	0.6722
11	207.80	17.0678	209.60	17.4502	1.80	0.9525
12	213.63	26.5293	215.67	25.5977	2.04	1.0429
13	247.77	47.2975	249.27	47.7645	1.50	‘1.0916
14	191.30	40.0553	192.20	39.9779	0.90	0.1943
15	233.07	74.9691	234.83	75.8928	1.76	0.9462
16	242.03	44.9213	243.73	46.1038	1.70	1.4549
17	234.77	48.3022	235.63	48.3525	0.86	0.0693
18	202.20	26.1207	202.97	26.1546	0.77	0.0300
19	208.97	57.9966	210.93	59.1084	1.96	1.1227
20	286.30	124.9445	288.60	126.8615	2.30	1.9468
21	224.93	71.1544	225.77	71.2917	0.84	0.1127
22	196.23	33.9082	197.53	34.8311	1.30	0.9730
23	220.60	39.8019	221.43	39.8424	0.83	0.0513
24	274.70	16.8964	276.20	18.1055	1.50	1.1778
25	283.70	81.6523	285.57	82.9051	1.87	1.2578
26	180.63	25.7030	181.87	25.0632	1.24	0.8517
27	212.03	55.9429	212.83	56.1090	0.80	0.1193
28	201.63	45.1673	202.47	45.3186	0.84	0.1060
29	251.27	105.7394	253.20	106.6091	1.93	1.0810
30	204.13	39.8814	205.47	40.8433	1.34	0.9935
31	178.41	97.6970	179.19	97.9234	0.78	0.2150
32	190.83	54.2209	191.60	54.3727	0.77	0.1290

sd - standard deviation

(Contd...)

Trt. No. 1 to 32 are the different nutrient treatments

Table 13 contd.. .)

Trt. No.	Initial basal area (cm^2)		Final basal area (cm^2)		Increment in basal area (cm^2)	
	mean	sd	mean	sd	mean	sd
33	250.73	50.1261	252.23	51.1118	1.50	1.1208
34	208.63	86.7545	209.87	87.4895	1.24	0.9406
35	247.13	47.0470	248.77	48.3990	1.64	1.3684
36	264.73	44.5439	266.17	44.8785	1.44	0.8477
37	213.23	28.9345	214.03	29.0287	0.80	0.0700
38	221.67	82.0373	222.90	82.7227	1.23	0.8322
39	242.97	12.0542	243.87	12.1541	0.90	0.0404
40	204.87	77.1380	205.63	77.2534	0.76	0.1044
41	206.13	28.0981	207.67	28.7253	1.54	1.2250
42	252.80	59.8267	254.63	60.7273	1.83	0.9355
43	228.97	34.8721	230.50	34.8431	1.53	1.1697
44	284.97	171.0822	285.90	171.4025	0.93	0.2501
45	230.50	67.3769	232.00	68.3956	1.50	1.2250
46	250.10	130.6358	252.03	131.9973	1.93	1.5242
47	179.70	78.0816	180.42	78.2440	0.72	0.1504
48	158.27	69.7499	158.97	69.9088	0.70	0.1582
49	276.80	62.9600	278.80	64.0084	2.00	1.0753
50	197.48	135.974	199.54	138.4254	2.06	2.4815
51	281.57	155.2517	283.40	157.1277	1.83	2.0532
52	180.63	86.7797	181.41	87.0149	0.78	0.1914
53	244.57	77.9886	246.10	79.1709	1.53	1.3502
54	246.90	28.7105	248.10	29.4444	1.20	0.7423
55	174.93	55.5910	175.70	55.6881	0.77	0.1153
56	224.67	55.4943	225.97	56.1436	1.03	0.8508
57	206.60	26.6152	207.43	26.6721	0.83	0.0624
58	199.97	46.6556	200.73	46.7701	0.76	0.1082
59	231.53	10.3196	232.43	10.3196	0.90	0.0289
60	223.33	11.5941	224.20	11.5469	0.87	0.0265
61	319.63	132.1573	320.80	132.3143	1.17	0.3197
62	213.57	34.6338	214.37	34.7304	0.80	0.0651
63	268.20	30.2303	269.50	30.5926	1.30	0.6678
64	237.57	38.1615	238.40	38.3077	0.83	0.1082

sd - standard deviation

Trt. No. 33 to 64 are the different nutrient treatments

Table 14. Mean values of Volume of trees at Pathiri 1981 plantation

Trt. No.	Initial Volume (m^3)		Final Volume (m^3)		Increment in Volume (m^3)	
	mean x 10^{-2}	sd	mean x 10^{-2}	sd	mean x 10^{-2}	sd
1	18.1267	0.011212	18.3467	0.011360	0.2200	0.000200
2	20.0300	0.026855	20.3433	0.027292	0.3133	0.000551
3	17.4700	0.007854	17.6633	0.008450	0.1933	0.000666
4	17.6000	0.020002	17.8100	0.020690	0.2100	0.000954
5	19.4900	0.021676	19.7267	0.022100	0.2367	0.000462
6	20.0767	0.050591	20.3800	0.052950	0.3033	0.002386
7	20.2100	0.020252	20.5567	0.020744	0.3467	0.001501
8	22.1167	0.033602	22.5567	0.036216	0.4400	0.002615
9	20.4533	0.033596	20.7500	0.034854	0.2967	0.001258
10	23.5533	0.006469	23.8600	0.006589	0.3067	0.000153
11	18.3733	0.006174	18.6400	0.006978	0.2667	0.000896
12	19.0400	0.005047	19.3267	0.004790	0.2867	0.000643
13	20.8033	0.017479	21.1000	0.018240	0.2967	0.001102
14	18.5000	0.011341	18.7067	0.011585	0.2067	0.000321
15	20.1100	0.030967	20.3633	0.032042	0.2533	0.001079
16	20.4300	0.022990	20.7300	0.023756	0.3000	0.001127
17	19.7033	0.024019	19.9333	0.024477	0.2300	0.000458
18	17.5633	0.019428	17.7600	0.019733	0.1967	0.000306
19	19.3933	0.030167	19.6333	0.031114	0.2400	0.000954
20	21.1333	0.053904	21.4767	0.055671	0.3433	0.001779
21	20.3367	0.024886	20.5600	0.025552	0.2233	0.000681
22	17.6600	0.012875	17.8433	0.013220	0.1833	0.000351
23	19.2033	0.011014	19.4200	0.011429	0.2167	0.000416
24	21.4267	0.013006	21.7133	0.013102	0.2867	0.000643
25	22.2133	0.037198	22.5100	0.038200	0.2967	0.001002
26	17.6300	0.015578	17.8400	0.015280	0.2100	0.000500
27	18.9033	0.021200	19.1133	0.021650	0.2100	0.000458
28	17.6400	0.025582	17.8467	0.026280	0.2067	0.000737
29	20.6433	0.049826	20.9133	0.050991	0.2700	0.001229
30	17.3900	0.019908	17.6600	0.021052	0.2700	0.001473
31	18.2133	0.050296	18.3967	0.051354	0.1833	0.001124
32	17.1900	0.018874	17.3733	0.019158	0.1833	0.000503

sd - standard deviation

(contd..)

Trt. No. 1 to 32 are the different nutrient treatments

Table 14 contd ….)

Trt. No.	Initial Volume (m3)		Final Volume (m^3)		Increment in Volume (m3)	
	mean x 10^{-2}	sd	mean x 10^{-2}	sd	mean x 10^{-2}	sd
33	19.8500	0.029550	20.1233	0.030400	0.2733	0.000874
34	18.4600	0.032618	18.6667	0.033716	0.2067	0.001150
35	20.3767	0.028081	20.6600	0.029161	0.2833	0.001102
36	21.2733	0.016772	21.5433	0.017039	0.2700	0.000520
37	18.6067	0.004895	18.8167	0.005133	0.2100	0.000265
38	19.0367	0.034686	19.2467	0.035570	0.2100	0.000889
39	18.6433	0.010597	18.9300	0.010320	0.2867	0.000416
40	19.0500	0.044573	19.2733	0.045094	0.2233	0.000702
41	18.6300	0.009102	18.8300	0.009462	0.2000	0.000361
42	20.3667	0.030160	20.6700	0.031248	0.3033	0.001124
43	18.9567	0.024768	19.2367	0.024444	0.2800	0.001114
44	22.2867	0.072866	22.5267	0.073900	0.2400	0.001044
45	19.0067	0.013754	19.2467	0.014566	0.2400	0.000954
46	20.1933	0.056514	20.4600	0.057969	0.2667	0.001464
47	17.2100	0.035693	17.3733	0.036516	0.1633	0.000862
48	17.2000	0.027520	17.3500	0.028333	0.1500	0.000854
49	22.1967	0.027999	22.5067	0.028899	0.3100	0.000964
50	18.1200	0.055013	18.3500	0.057224	0.2300	0.002211
51	21.9967	0.073971	22.3100	0.075898	0.3133	0.001930
52	17.5200	0.028629	17.7033	0.029645	0.1833	0.001069
53	19.6767	0.027659	19.9233	0.028551	0.2467	0.000902
54	21.0667	0.012423	21.3233	0.012894	0.2567	0.000473
55	17.3933	0.025325	17.5600	0.025873	0.1667	0.000551
56	19.6767	0.035691	19.9633	0.036965	0.2867	0.001343
57	8.6400	0.022194	18.8367	0.022562	0.1967	0.000404
58	18.4167	0.014283	18.6167	0.014581	0.2000	0.000361
59	18.8200	0.009440	19.0533	0.009585	0.2333	0.000153
60	19.2500	0.005957	19.4633	0.006030	0.2133	0.000115
61	25.5433	0.080550	25.8600	0.081287	0.3167	0.000737
62	8.8300	0.021403	19.0467	0.021805	0.2167	0.000416
63	21.7000	0.023506	21.9767	0.023938	0.2767	0.000513
64	20.7400	0.029469	20.9767	0.029393	0.2367	0.000603

sd - standard deviation

Trt. No. 33 to 64 are the different nutrient treatments

Table 15. Initial, final and increment (minimum and maximum) in height of trees and respective nutrient treatments in the different plantations

Study sites	Height (m)					
	Initial		Final		Increment	
	minimum	maximum	minimum	maximum	minimum	maximum
Aravallikkavu 1991	0.84 $N_3P_0K_2Ca_3Mg_3$	2.63 $N_0P_2K_3Ca_1Mg_0$	3.34 $N_3P_0K_2Ca_3Mg_3$	5.20 $N_0P_2K_3Ca_1Mg_0$	2.44 $N_0P_0K_0Ca_0Mg_0$	2.68 $N_2P_1K_0Ca_1Mg_3$
Aravallikkavu 1990	1.51 $N_1P_2K_2Ca_0Mg_1$	3.15 $N_0P_2K_3Ca_1Mg_2$	4.28 $N_0P_0K_0Ca_0Mg_0$	6.58 $N_0P_2K_3Ca_1Mg_2$	1.45 $N_0P_0K_0Ca_0Mg_0$	3.59 $N_2P_2K_2Ca_2Mg_2$ $N_0P_1K_2Ca_3Mg_1$ $N_1P_1K_3Ca_2Mg_0$ $N_1P_0K_0Ca_1Mg_1$ $N_3P_0K_3Ca_3Mg_3$
Valluvasseri 1991	1.17 $N_3P_2K_1Ca_2Mg_1$	3.08 $N_0P_0K_0Ca_0Mg_2$	3.40 $N_3P_1K_1Ca_0Mg_2$	5.39 $N_0P_0K_0Ca_0Mg_2$	2.14 $N_0P_0K_0Ca_0Mg_0$	2.38 $N_2P_2K_2Ca_2Mg_2$
Valluvasseri 1990	1.84 $N_1P_1K_3Ca_2Mg_2$	3.82 $N_2P_3K_3Ca_0Mg_3$	3.94 $N_0P_0K_0Ca_1Mg_3$	5.99 $N_2P_3K_3Ca_0Mg_3$	2.00 $N_0P_0K_0Ca_0Mg_0$	2.25 $N_2P_2K_2Ca_2Mg_2$
Nellikkutha	5.20 $N_2P_2K_1Ca_3Mg_2$	12.10 $N_3P_3K_2Ca_1Mg_0$	6.49 $N_2P_2K_1Ca_3Mg_2$	13.33 $N_3P_3K_2Ca_1Mg_0$	1.03 $N_0P_0K_1Ca_0Mg_0$	1.32 $N_3P_1K_1Ca_1Mg_1$
Pathiri	8.22 $N_1P_3K_0Ca_2Mg_1$	13.44 $N_3P_3K_3Ca_1Mg_0$	8.48 $N_1P_3K_0Ca_2Mg_1$	13.77 $N_3P_3K_3Ca_1Mg_0$	0.25 $N_0P_2K_3Ca_0Mg_1$	0.38 $N_2P_3K_3Ca_1Mg_2$

Table 16. Initial, final and increment (minimum and maximum) in basal area of trees and respective nutrient treatments in the Nellikkutha and Pathiri plantations

Study sites	Basal area (cm2)					
	Initial		Final		Increment	
	minimum	maximum	minimum	maximum	minimum	maximum
Nellikkutha	26.20 $N_2P_2K_1Ca_3Mg_2$	93.55 $N_2P_2K_2Ca_2Mg_2$	28.08 $N_2P_2K_1Ca_3Mg_2$	100.09 $N_2P_2K_2Ca_2Mg_2$	0.00 $N_0P_0K_0Ca_0Mg_0$	8.87 $N_3P_1K_1Ca_1Mg_1$
Pathiri	158.27 $N_2P_1K_0Ca_0Mg_0$	319.63 $N_3P_3K_3Ca_1Mg_0$	158.97 $N_2P_1K_0Ca_0Mg_0$	320.80 $N_3P_3K_3Ca_1Mg_0$	0.70 $N_2P_1K_0Ca_0Mg_0$	2.87 $N_0P_2K_3Ca_1Mg_2$

Table 17. Initial, final and increment (minimum and maximum) in volume of trees and respective nutrient treatments in the Nellikkutha and Pathiri plantations

Study sites	Volume(m^3x10^{-2})					
	Initial		Final		Increment	
	minimum	maximum	minimum	maximum	minimum	maximum
Nellikkutha	12.83 $N_2P_2K_1Ca_3Mg_2$	15.53 $N_2P_2K_2Ca_2Mg_2$	12.96 $N_2P_2K_1Ca_3Mg_2$	16.17 $N_2P_2K_2Ca_2Mg_2$	0.1200 $N_0P_0K_0Ca_0Mg_0$	0.6350 $N_2P_2K_2Ca_2Mg_2$
Pathiri	17.19 $N_0P_0K_0Ca_0Mg_2$	25.54 $N_3P_3K_3Ca_1Mg_0$	17.37 $N_0P_0K_0Ca_0Mg_2$ $N_1P_3K_0Ca_2Mg_1$	25.86 $N_3P_3K_3Ca_1Mg_0$	0.1500 $N_2P_1K_0Ca_0Mg_0$	0.4400 $N_2P_2K_1Ca_3Mg_0$

3.5. General Discussion

In the one and two year old (1991 and 1990) teak plantations at Aravallikkavu, it could be seen that there was no general trend with respect to the effect of nutrients on height growth of trees. But the increment in tree height revealed that minimum increment was recorded in the control treatment, in both plantations. The maximum values were recorded in the five different nutrient treatments *viz.*, $N_2P_2K_2Ca_2Mg_2$, $N_3P_0K_3Ca_3Mg_3$, $N_0P_1K_2Ca_3Mg_1$, $N_1P_1K_3Ca_2Mg_0$ and $N_1P_0K_0Ca_0Mg_1$. The mean height increment was 1.09 times in the $N_2P_2K_2Ca_2Mg_2$ treatment in the 1991 plantation and 2.48 times in the above five treatments in the 1990 when compared with the control.

On a perusal of the results of the tree height in the Valluvasseri plantations, it was possible to see that there was an increment of 1.11 and 1.13 times in the 1991 and 1990 plantations in the $N_2P_2K_2Ca_2Mg_2$ treatment when compared with the control. In both cases, the lowest increment in height was recorded in the control.

The height of trees in the Nellikkutha teak plantation as well as that in the Pathiri showed that the 'increment in height of trees was 1.11 and 1.12 times in the $N_2P_2K_2Ca_2Mg_2$ and $N_2P_3K_3Ca_1Mg_2$ treatments when compared with the control, respectively. The actual increment values were very low.

The basal area of trees in the Nellikkutha plantation showed that there was no appreciable increment in the control treatment while an increment upto 8.87cm^2 was observed in $N_3P_1K_1Ca_1Mg_1$ treatment. Volume increment values revealed that there was an increment of 5.29 times in the $N_2P_2K_2Ca_2Mg_2$ treatment when compared with the control.

In the Pathiri plantation, the basal area increment was 1.72 times in $N_0P_2K_3Ca_1Mg_2$ treatment when compared with the control. The volume increment was 1.47 times in the $N_2P_2K_1Ca_3Mg_0$ treatment in comparison to the control. It was seen that the basal area and volume increments were lowest in the same treatment *viz.*, $N_2P_1K_0Ca_0Mg_0$ while the highest increments were in different treatments.

Statistical analyses indicated that there was no significant difference in the final height of trees due to nutrient treatments in both the younger and older plantations so also for basal area and volume in older plantations. Analysis of variance showed that the differences in increment in height was mainly attributable to the significant influence of nutrient treatments in the younger plantations, Aravallikkavu 1990 and Valluvasseri 1990 and 1991 plantations. In the case of older plantations, Nellikkutha 1981 and Pathiri 1981, there was no significant difference in increment in height, basal area and volume of trees due to nutrient treatments.

Similar results of non-significant effects on basal area and volume increment of older plantations were recorded by Prasad *et a1* (1986) for 10 and 20 year old plantations of West Mandala. The reason may be that the nutritional requirements of the older plantations would be higher than the dose applied, resulting in non-significant increase in tree volume. The effect of fertilisers on the height of younger plqtations corroborates the findings of Kishore (1987) for the teak plantations in Chandrapur, Maharashtra.

The response function fitted to growth increments showed very low adjusted R^2 values in all the plantations. The poor response obtained is suspected to be due to some external factors mainly light, prevailing microclimate, variation in soil properties and other management aspects.

The best group of nutrient treatments with respect to height increment was arrived at by the use of mean comparison test (LSD). Out of the 64 nutrient treatments, in the Valluvasseri 1990 plantation, the best group, which is significantly different from all the others, contains the treatments *viz.*,. $N_3P_2K_0Ca_2Mg_1$ and $N_2P_2K_2Ca_2Mg_2$ Among these two treatments, the mean height increment value obtained for $N_2P_2K_2Ca_2Mg_2$ (2.25cm) was slightly higher than that obtained in $N_3P_2K_0Ca_2Mg_2$ (2.23cm) treatment (Table 7).
Mean comparison test was carried out for data on height increment in Valluvasseri 1991 plantation. Pair-wise comparison between the nutrient treatments showed that the treatment, $N_2P_2K_2Ca_2Mg_2$ was significantly different from all the other treatments with respect to height increment (Table 8).

It was seen that $N_2P_2K_2Ca_2Mg_2$ treatment *i.e* application of 65g of Urea, 150g of Mussorie rock phosphate, 58g of Muriate of Potash, 42g of quick lime and 149g of Magnesium sulphate/ plant in the first year was the common best treatment in the Aravallikkavu 1990 and Valluvasseri 1991 and 1990 teak plantations. This is equivalent to application of 163kg of Urea, 375kg of Mussorie rock phosphate, 145kg of Muriate of potash, 105kg of Quick lime and 373kg of Magnesium sulphate/ha. Thus addition of the above doses in split doses during south-west and north-east monsoon periods and double the above amount in split doses in the second and third years during the two monsoon periods was found to be the common best treatment.

The available P content of the soil at Aravallikkavu was not within the detectable limits. The general fertility of soils in the third rotation plantations was found to be very low. Hence even the addition of small amount of nutrients could produce considerable effect on the growth. This is discernible in the present study. This may be a reason for the significant effect of nutrients on height increment in respect of younger plantations. In older plantations, as the trees were in both vegetative as well as reproductive growth phases, the added nutrients may not be enough to have significant effect on either height, basal area or volume. Perhaps higher doses than those applied here might produce different results.

The non-significant effect of nutrients on the height increment of trees in the one year old (1991) plantation at Aravallikkavu which was in the third rotation and growing in highly degraded soils revealed that precise site evaluation and detailed soil analyses have to be carried out before recommendation of nutrients and their dosages. This also suggests that nutrient recommendation should be site specific and cannot be generalised.

4. CONCLUSIONS

1. The study in the younger teak plantations in the third rotation and older plantations in the second and first rotations under different soil conditions showed that there was significant effect on the increment in height of younger plantations while there was no effect on increment in height, basal area and volume of trees in older plantations due to the application of nutrients.

2. Among the different nutrient treatments, $N_2P_2K_2Ca_2Mg_2$ ie application of 65g of Urea, 150g of Mussorie rock phosphate, 58g of Muriate of potash, 42g of Quick lime and 149g of Magnesium sulphate/ plant or 163kg of Urea, 375kg of Mussorie rock phosphate, 145kg of Muriate of potash, l05kg of Quick lime and 373kg of Magnesium sulphate /ha in split doses in the first year during south-west and north-east monsoon periods and double the above amount in split doses in the second and third years during the two monsoon periods was found to be the best.

3. The study revealed that precise site evaluation and detailed soil analyses have to be carried out before recommending the dosage for fertilisers.

4. The nutrient requirements and the dosage are site specific.

5. For older plantations, further research is needed to arrive at the required nutrient dosage.

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