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ENHANCEMENT OF PRODUCTIVITY IN EUCALYPTUS THROUGH FERTILIZER INPUTS AND OTHER COST EFFECTIVE TREATMENTS

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ABSTRACT

This project was undertaken to study the effect of various silvicultural treatments and nutrient combinations on the growth and volume of eucalypts and to evaluate the nutrient uptake and partitioning in different parts of the plant.

Experimental plots were laid out in the grasslands at Vallakkadavu and seedlings of *Eucalyptus grandis* planted over an area of 80 ha. Nine silvicultural treatments viz three pit sizes of 20 cm x 20 cm x 20 cm , 30 cm x 30 cm x 30 cm and 40 cm x 40 cm x 40cm ; three spacings of 2 m x 2 m, 2.5 m x 2.5 m and 3 m x 3 m and three skinning operations of line, complete and around the plant and 16 nutrient combinations of Nitrogen (N), Phosphorus (P) and Potassium (K) were tried. Fertilisers with four levels viz 0, 15, 30 and 40 g/plant of each of the nutrients were added initially in the pit before planting (June), during north - east monsoon (October) in the first year and south - west monsoon (June) in the second year with double the dose of that applied during the first year.

Height was measured at three months intervals during the first year and at six months interval thereafter upto three years. Girth at breast height (gbh) was recorded at the end of 36 months of planting and the volume of trees were estimated using a prediction equation. The relative treatment effectiveness (RTE) and relative economic effectiveness (REE) were also worked out.

In addition to this, trees, one each with height and gbh close to the mean value in each silvicultural treatment and nutrient combination, were harvested at the end of 36 months and the nutrient accumulation in different parts was estimated.

Another experiment with high density planting with 1 m x m spacing was also conducted employing the same 16 nutrient combinations in three pit sizes of 20 cm x 20 cm x 20 cm, 30 cm x 30 cm x 30 cm and 40 cm x 40 cm x 40 cm in completely skinned plots at Vallakkadavu. The height and gbh of trees were recorded and

volume of trees estimated. The RTE and REE were worked out. The nutrient accumulation in different parts of the trees was also found out.

In order to evaluate the effect of the best set of silvicultural treatments and nutrient combinations found out at Vallakkadavu, multilocational trials were conducted with *E. tereticornis* seedlings at Punalur and Kottappara. The height of the trees was recorded at the end of 6, 12, and 24 months after planting.

It was found that there was significant difference in height of *E. grandis* trees due to various silvicultural treatments and nutrient combinations. Among the various silvicultural treatments, 3 m x 3 m spacing, 20 cm x 20 cm x 20 cm pit size and line skinned treatment was found to be the best in terms of volume, RTE and REE values. Among the different nutrient combinations, $N_2P_2K_1$ *i.e.*, application of 30 g N, 30 g P and 15 g K/tree or 65 g Urea, 150 g Mussorie rock phosphate and 29 g Muriate of potash/tree for one application in the first year was found to be the best. This is equivalent to 72.438 kg of Urea, 166.650 kg of Mussorie rock phosphate and 32.053 kg of Muriate of potash/ ha (for 2500 plants).

The study on the nutrient accumulation at different parts of the trees revealed that the amount of nutrients in bolewood was two times of that in branches and one and half times of that in leaves.

The multilocational trials showed that the best set of silvicultural treatments and nutrient combinations for *E. grandis* were equally matching for *E. tereticornis* at lower elevations. In the high density planting with l m x lm spacing, pressure on land, the establishment cost and the cost of fertilisers were very high. The RTE and REE values were considerably lower than those in wider spacings.

The findings are on the basis of observations for the first three years only and therefore in order to establish the results, the observations will have to be recorded continuously till the trees are finally felled at the rotation period of seven years.

1. INTRODUCTION

Eucalyptus is a commonly planted tree species in Kerala in all forestry programmes owing to its wider adaptability, fast - growing habit and high industrial demand. It was introduced during 1970s on a large scale under plantation programme and there are about 30,000 ha of *E. tereticornis* and *E. grandis* plantations under the Forest Department (Govt. of Kerala, 1992).

In the existing plantations, the yield varies from one location to another. The average yield for *E. tereticornis* was 73 m^3/ha where as for *E. grandis,* it was 137 m^3/ha at the rotation age of 10-years (Jayaraman and Krishnankutty, 1990). The annual demand from the pulp and paper industries was 0.30 million tonnes while the available eucalypt material in 1989-90 was only 0.1 12 million tonnes (Govt. of Kerala, 1990).

This reveals that the demand far exceeds the production, whereas the productivity has declined considerably. In order to meet the demand, it is necessary either to bring large land area under this species or to make out all efforts to increase the productivity of the existing plantations. The former is impossible due to many socioeconomic constraints while the latter happens to be the most acceptable option for future development of forestry in Kerala, especially where land availability for expansion is minimum.

Plantation forestry has until recently been practiced with traditional silvicultural practices. This has resulted in impoverisation of soil fertility and hence poor tree establishment and growth. Now, more than ever, the importance of an adequate supply of plant nutrients along with suitably modified planting techniques is being recognised to ensure efficient crop production. Judicious management of tree nutrition *inter alia* advanced planting techniques is an important tool not only to ensure increased production, but also for sustained productivity over a long period.

Although the importance of fertilisers in Indian forestry was recognised as early as 1910 during dune afforestation programme (Ghosh, 1977), their use could not make much progress because of low priority given to forestry sector and the general belief that nutrient cycling in forest ecosystem is inexhaustible and renewable in nature. Fertiliser experiments in the forest plantations on an operational basis, however, began only in 1950s.

Studies on the effect of fertilisers on eucalypts showed that growth can be increased by 50 to 60% (Bonny, 1991; Gupta, 1990). Significant increase in growth of *E. grandis* was recorded by the addition of fertilisers (Grewal *et al,* 1992; Jones and Dighton, 1993; Krishnamoorthy and Vijayan, 1986; Singh *et al,* 1991; Valeri *et al,* 1993 and Wilkins, 1990). Research on fertiliser application showed economic gains from applying N even to visibly healthy forest stand (Cromer *et al,* 1993).

It has been reported that biomass production can be increased and the rotation period reduced with the application of fertilisers in plantations (Bahuguna, 1991; Kane *et al,* 1992). Schonau (1983) found an increase of 25 to 98 m^3/ha over a rotation of 10 years as a result of fertiliser application in *E. grandis* plantation in S. Africa. An increase of 73% in total above ground biomass of *E. tereticornis* due to the addition of 10 and 20 kg of single superphosphate was reported by Gupta and Mohan (1989). Another finding was that growth depended on time of application, local site conditions etc (Buck, 1987).

Eucalypts are usually grown as energy plantations which involve the planting of tree species at close spacing in order to have maximum biomass production per unit area and adopting economic methods with respect to planting operations (Raizada and Padmaiah, 1993). This makes it imperative for different silvicultural practices to be tried out for evaluating their effect on yield.

Chauhan *et al* (1983) found that tree height and diameter reduced at close spacing. Best growth at four year old of *E. tereticornis* was found in 3m x 3m spacing by Bhatia (1980). It was also pointed out by Schonau *et al* (1981) that diameter of the planting pit is more important than the pit depth.

In Kerala, except some sporadic attempts, no systematic work has been carried out to study the effect of the application of nutrients in combination with silvicultural treatments on the growth of eucalypt (Alexander and Mary, 1984; Prasad *et al*, 1984 a,b).

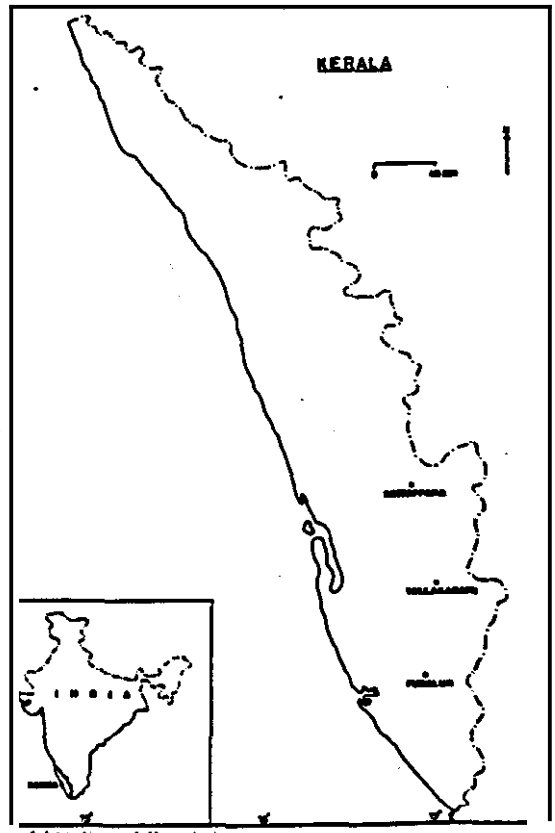
This project was undertaken with the aim of enhancement of productivity in eucalypts through fertiliser inputs and other cost effective silvicultural treatments. The objectives were

1. to study the effect of different silvicultural treatments and nutrient combinations on the growth and volume of eucalypts and
2. to evalute the nutrient uptake and partitioning in different parts of the tree by destructive sampling.

2 MATERIALS AND METHODS

2.1. Study area

The study was conducted in the grasslands at Vallakkadavu, lying in the Grassland Afforestation Division, Peerumedu (Fig. 1). The area was hilly with an average elevation of 875 m asl and 20-30% slope. The rainfall was 3,125 mm per annum with an average minimum temperature of 8°C and maximum of 37°C. The soil was severely truncated and belong to skeletal isothermic family of Lithic Dystropepts developed from Charnockites rich in biotite mica with occasional gneissic bunds (Prasad *et al,* 1984a).



g1. Location of the study area

An area of about 80 ha was cleared in April 1992 and planted with *E. grandis* in May - June. The seedlings were collected from the mother nursery at Uppupara of Social Forestry Wing of Kerala Forest Department. The naked seedlings from the mother nursery were transported to Vallakkadavu and transplanted into polythene bags.

2.2. Soil status

Fifteen soil pits were taken from different locations of the experimental area and samples were collected from 0-20,2040 and 40-60 cm layers of soil pits. Analyses were carried out for soil pH, organic carbon, total N, available P and K. cation exchange capacity (CEC) as per standard procedures described in ASA (1965) and Jackson (1958). Soil texture was also determined.

The physical and chemical properties of soils are given in Table 1. The soil was clay loam and strongly acidic in the surface and loam and medium acidic in deeper layers. It contained high organic carbon in all the three layers. The ratios of organic carbon : total N were 14.78, 19.11 and 15.33 in the surface, sub surface and 40-60 cm layers, respectively. The available P status was very low and the K content was found to be high. The CEC varied from 13 to 16 me/l00g soil.

Table I. Physical and chemical properties of soils in different layers of soil pits at Vallakkadavu, Kottappara and Punalur

Properties	Layers (cm)								
	0-20			20-40			40-60		
	V	K	P	V	K	P	V	K	P
Sand %	67	82	84	64	80	82	62	78	81
Silt %	22	10	8	19	11	13	17	12	12
Clay %	21	8	11	17	9	9	21	10	7
Textural Class	CL	LS	SL	L	LS	LS	L	LS	LS
Soil pH	5.4	6.1	6.2	5.6	6.2	6.1	5.6	6.2	6.0
Org. carbon %	3.40	1.35	1.48	1.72	0.92	0.81	0.92	0.67	
Total N%	0.23	0.09	0.10	0.09	0.06	0.06	0.06	0.04	0.03
Av. P ppm	8	6	5	4	3	3	3	2	2
Av. K ppm	40	20	23	21	12	11	16	9	6
CEC me/l00g	16	21	I8	13	17	17	13	15	12

2.3. Experimental treatments

There were nine silvicultural treatments and 16 fertiliser combinations tried. The different silvicultural treatments and fertiliser combinations are described separately.

2.3.1. Silvicultural treatments

The nine silvicultural treatments were three spacings *viz* 2 m x 2 m, 2.5 m x 2.5 m and 3 m x 3 m, three pit sizes of 20 cm x 20 cm x 20 cm, 30 cm x 30 cm x 30 cm and 40 cm x 40 cm x 40cm and three skinning operations viz line, complete and around the plant.

They were given the notations as given below.

$A_1B_IC_1$; $A_1B_2C_3$; $A_1B_3C_2$; $A_2B_1C_3$; $A_2B_2C_2$; $A_2B_3C_1$; $A_3B_1C_2$; $A_3B_2C_1$ and $A_3B_3C_3$

where A_1, A_2 and A_3 were 2 m x 2 m, 2.5 m x 2.5 m and 3 m x 3 m spacings, respectively; B_1, B_2 and B_3 were 20 cm x 20 cm x 20 cm, 30 cm x 30 cm x 30 cm and 40 cm x 40 cm x 40 cm pit sizes , respectively and C_1, C_2 and C_3 were various skinning operations viz. line, complete and around the plant.

2.3.2. Nutrient combinations

Sixteen nutrient combinations tried for the experiment were four levels, each, of N in the form of Urea, P in the form of Mussorie rock phosphate and K in the form of Muriate of potash were applied. The levels were 0, 15,30 and 45 g/plant.

The different nutrient combinations were

$N_0P_0K_0$; $N_0P_1K_2$; $N_0P_2K_3$; $N_0P_3K_1$; $N_1P_0K_1$; $N_1P_1K_3$; $N_1P_2K_2$; $N_1P_3K_0$; $N_2P_0K_2$; $N_2P_1K_0$; $N_2P_2K_1$; $N_2P_3K_3$; $N_3P_0K_3$; $N_3P_1K_1$; $N_3P_2K_1$ and N_3P_3

where N_0, N_1, N_2 and N_3 were Nitrogen ; P_0, P_1, P_2 and P_3 were Phosphorus and K_0, K_1, K_2 and K_3 were Potassium each @ 0, 15.30 and 45 g/plant.

The quantity of fertilisers added/ha in 2 m x 2 m , 2.5 m x 2.5 m and 3 m x 3 m spacings for three applications are given in Table 2. They were 326, 652 and 978 kg/ha of Urea for 15, 30 and 45 g of Nitrogen/plant, respectively; 750, 1500 and 2250 kg/ha of Mussorie rock phosphate for 15, 30 and 45 g of Phosphorus/plant,

repectively and 288.50, 577.00 and 865.50 kg/ha of Muriate of potash for 15, 30 and 45 g of Potassium/plant in 2 m x 2 m spacing, respectively.

Table 2. Quantity of fertilisers (kg) added/ha in different spacings for three applications

Fertilisers added	Quantity of fertilisers (kg) added/ha in different spacings			
Dose(g/plant)	1 m x 1m	2 m x 2m	2.5m x 2.5m	3m x 3m
Urea for N				
15	1304.00	326.00	208.64	144.87
30	2608.00	652.00	417.28	289.75
45	3912.00	978.00	625.92	434.62
MRP for P				
15	3000.00	750.00	480.00	333.30
30	6000.00	1500.00	960.00	666.60
45	9000.00	2250.00	1440.00	999.90
MOP for K				
15	1154.00	288.50	184.64	128.21
30	2308.00	577.00	369.28	256.42
45	3462.00	865.50	553.92	384.63

In 2.5 m x 2.5 m spacing, 208.64, 417.28 and 625.92 kgha of Urea; 480, 960 and 1440 kg/ha of Mussorie rock phosphate and 184.64, 369.28 and 553.92 kg/ha of Muriate of potash were applied, the former for N and the latter two for P and K, respectively, each for 15, 30 and 45 g/plant. In the 3 m x 3 m spacing, 144.87.289.75 and 434.62 kg/ha of Urea, 333.30, 666.60 and 999.90 kg/ha of Mussorie rock phosphate and 128.21, 256.42 and 384.63 kg/ha of Muriate of potash were added, the former for N and the latter two for P and K, respectively, each for 15, 30 and

2.4. Experimental design

The experiment was carried out in a split plot design with nine silvicultural treatments forming the levels of the main plot factor and 16 nutrient combinations constituting the levels of the sub plot factor. Both main and sub plot treatments had a fractional factorial structure. The experiment was replicated five times. Thus there were nine main plots within a replication. Planting pattern of a single main plot in the whole experiment is shown in Fig. 2. There were 12,600 seedlings in each experiment. Each main plot was surrounded by border plants in all sides as shown in Fig. 2.

Under each silviculatural treatment, there were 16 nutrient combinations. One nutrient combination was applied to three columns with 25 plants in one column. The plants in the middle column were taken for observational purposes.

2.5. Mode of application of fertilisers

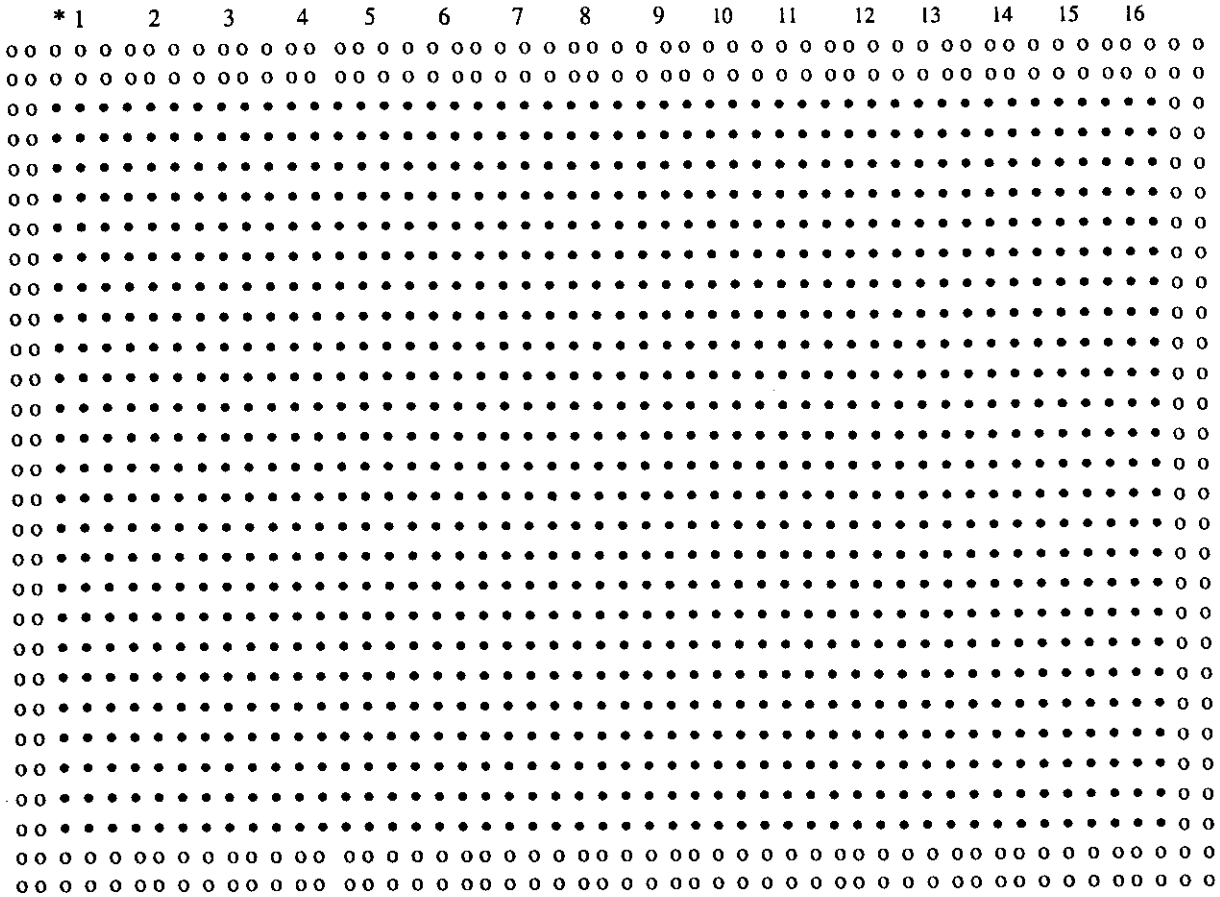
Fertilisers were added in the soil pits before planting in June 1992 and at the surface during north-east monsoon (October-November 1992) in the first year, the latter around the plant in a furrow 5 cm deep and 10 cm away from the plant, thoroughly mixed with the soil and then the furrow was filled with soil.

Further application of fertilisers was carried out during the second year, but only once, with double the dose of that applied in the first year during south - west monsoon (June- July 1993) in the same manner of the second application in the first year about 15 cm away from the plant.

2.6. Growth measurements

The height of seedlings was measured at the time of planting and at three months interval during the first year and six months interval during second and third years. The casualties which amounted to be 15% were replaced in June 1993. The height

Fig. 2. Pictorial representation of the planting pattern for a single main plot.



o - Border plants

• - Treated plants

* - Different nutrient combinations *viz.*,

1. $N_0P_0K_0$	2. $N_0P_1K_2$	3. $N_0P_2K_3$	4. $N_0P_3K_1$
5. $N_1P_0K_1$	6. $N_1P_1K_3$	7. $N_1P_2K_2$	8. $N_1P_3K_0$
9. $N_2P_0K_2$	10. $N_2P_1K_0$	11. $N_2P_2K_1$	12. $N_2P_3K_3$
13. $N_3P_0K_3$	14. $N_3P_1K_1$	15. $N_3P_2K_1$	16. $N_3P_3K_2$

measurements were taken till 36th month and the girth at breast height (gbh) was also recorded at 36 months after planting.

The mean values for height of trees during second and third years were calculated excluding the casualties replaced during the second year. The girth at breast height (gbh) of trees was also recorded excluding casualties.

2.7. Statistical analyses

Height and gbh of trees were statistically analysed through split plot ANOVA separately for each period in order to evaluate the effect of the silvicultural treatments and nutrient combinations (Snedecor and Cochran, 1965).

2.8. Volume of trees

The volume of each tree was estimated using the prediction equation reported by Chathurvedi and Pande (1973) which is

$$V = -0.0009 + 0.3360\ D^2H$$

where V is the volume of trees (m^3); D is the diameter at breast height (m) and H is the height (m).

As most of the diameter values at breast height of the trees were outside the range of reliable prediction by the volume prediction equation, no statistical analysis was carried out on predicted values of volume.

2.9. Plant analysis

At the end of the experiment, trees with height and gbh close to the respective mean values in each silvicultural treatment and nutrient combination were harvested. The nutrient contents N, P and K in bolewood, branches and leaves of trees in

each silvicultural treatment and nutrient combination were found out using the procedures in Wilde *et al.* (1972). Nitrogen was determined by Kjeldahl's digestion followed by distillation method, P by spectrophotometry and K by flame photometry.

2.10. Relative treatment effectiveness (RTE)

On the basis of the volume of trees in control and different treatments, the relative treatment effectiveness (RTE) was calculated as

$$RTE = 100 \times \frac{(\text{volume in treatment} - \text{volume in control})}{\text{volume in control}}$$

where control is $N_0P_0K_0$ in each silvicultural treatment

2.11. Relative economic effectiveness (REE)

From the values of relative treatment effectiveness (RTE), relative economic effectiveness (REE) was calculated as

$$REE = RTE \times \frac{(\text{cost in control})}{\text{cost due to treatment}}$$

2.12. High density planting experiment with 1 m x 1 m spacing

With a view to study the performance of high density plantation, another experiment with 1 m x Im spacing in completely skinned area in three pit sizes of 20 cm x 20 cm x 20 cm, 30 cm x 30 cm x 30 cm and 40 cm x 40 cm x 40 cm were undertaken at Vallakkadavu. For this, seedlings were collected from the mother nursery at Uppupara of Social Forestry wing of Kerala Forest Department.

The experiment was carried out in split plot design with three silviculural treatments viz

Im x Im spacing, 20 cm x 20 cm x 20 cm pit size and complete skinning

Im x lm spacing, 30 cm x 30 cm x 30 cm pit size and complete skinning

Im x Im spacing, 40 cm x 40 cm x 40 cm pit size and complete skinning and 16 nutrient combinations as in 2. 3. 2.

The three silvicultural treatments formed the levels of main plot factor and the 16 nutrient combinations formed the levels of sub plot factor. The experiment was replicated twice. The number of plants in each replication was 1250.

The quantity of fertilisers added/ha is given in Table 2. They were 1304, 2608 and 3912 kg of Urea; 3000, 6000 and 9000 kg of Mussorie rock phosphate and 1154, 2308 and 3462 kg of Muriate of potash, the former for N and the latter two for P and K, respectively, each for 15, 30 and 45 g/plant. The amount of fertilisers added/ha in 1m x lm spacing was 4, 6.3 and 9 times of those applied in 2 m x 2 m, 2.5 m x 2.5 m and 3 m x 3 m spacing.

Regular observations on height at three months interval during the first year and at six months interval during second and third years were taken. The gbh of trees was also recorded at 36 months after planting. The casualties amounting to be 13% were replaced during the second year (1993). The mean values for height of trees during second and third years were calculated excluding casualties replaced during the second year. The gbh of trees was also recorded excluding casualties.

Statistical analyses of the data on height and gbh of trees were carried out using split plot ANOVA at each period separately (Snedecor and Cochran, 1965). The volume of trees was computed using the equation as mentioned in 2. 8 above.

At the end of the experiment, trees with height and gbh close to the respective mean values in each silvicultural treatment and nutrient combination were harvested. The nutrient contents N, P and K in bolewood, branches and leaves of trees in each silvicultural treatment and nutrient combination were found out using the procedures in Wilde *et al* (1972). Nitrogen was determined by Kjeldahl's digestion followed by distillation method, P by tri acid digestion followed by reduction with ascorbic acid and read at 660 nm using spectrophotometer and K by flame photometry.

2.13. Multilocational trials

On the basis of year round observation on height of trees, using the best set of silvicultural treatments and nutrient combinations, multilocational trials were conducted with *E. grandis* seedlings at Muthanga and with *E. tereticornis* at Kottappara and Punalur in 1993 (Fig. 1).

Three soil pits were taken from Punalur and Kottappara and samples collected from 0-20 cm, 20-40 cm and 40-60 cm layers. The soils were analysed for pH, organic carbon, total N, available P and K and CEC as per standard procedures described in ASA (1965) and Jackson (1958). Soil texture was also determined.

The experiment was carried out in split plot design with four silvicultural treatments *viz.*

$A_1B_3C_2$ (2 m x 2 m spacing, 40 cm x 40 cm x 40 cm pit size & complete skinning),
$A_2B_2C_2$ (2.5 m x 2.5 m „ ,30 cm x 30 cm x 30 cm „ & „),
$A_2B_3C_1$(2.5 m x 2.5 m „ ,40 cm x 40 cm x 40 cm „ & line skinning) and
$A_3B_IC_2$ (3 m x 3 m „ ,20 cm x 20 cmx 20 cm „ & complete skinning)
and eight nutrient combinations *viz*

$N_IP_1K_0$, $N_IP_IK_2$, $N_IP_3K_0$, $N_IP_3K_2$, $N_3P_IK_0$, $N_3P_IK_2$, $N_3P_3K_0$ and $N_3P_3K_2$
where N_1 and N_3 were N @ 15 and 45 g/plant; P1 and P3 were P @ 15 and 45 g/plant and K_0 and K_2 were K @ 0 and 30 g /plant.

The experiment was replicated five times. The experiment at Muthanga was abandoned due to the damage caused to the site by wild animals, mainly deer.

Growth measurements were taken at six, 12 and 24 months after planting. Statistical analyses of the data on height were carried out using split plot ANOVA at each period separately. The mean values of height of trees were calculated during the second year excluding the casualties replaced during the second year.

3. RESULTS AND DISCUSSION

Mean values of height, gbh and volume of trees in different silvicultural treatments and nutrient combinations and in high density planting with 1 m x Im spacing are given in Tables 3,4,5 and 6. Tables 7,8 and 9 depict of nutrient accumulation in the various parts of the tree in different silvicultural treatments and nutrient combinations.

3.1. Effect of different silvicultural treatments and nutrient combinations on height, gbh and volume of trees

3.1.1. Silvicultural treatments

There was considerable increase in the height of trees at different periods in various silvicultural treatments (Table 3). It was found that maximum mean height at three months after planting, 15.27 cm, was recorded in A1B2C3 (2 m x 2 m spacing, 30 cm x 30 cm x 30 cm pit size and skinning around the plant). Maximum mean height was recorded in AlBlCl (2 m x 2 m spacing, 20 cm x 20 cm x 20 cm pit size and line skinning) at six months after planting (43.18 cm) and in A3BlC2 (3 m x 3 m spacing, 20 cm x 20 cm x 20 cm pit size and complete skinning) at nine months after planting (58.51 cm), 12 (91.13 cm), 18 (135.62 cm) and 24 months (165.40 cm) after planting. They were in A3B2C1 (3 m x 3 m spacing, 30 cm x 30 cm x 30 cm pit size and line skinning) at 30 months after planting (289.40 cm) and in A1B3C2 (2 m x 2 m spacing, 40 cm x 40 cm x 40 cm pit size and complete skinning) at 36 months (356.16 cm) after planting.

The per cent mean height increase varied from 180 to 217 (at six months after planting), 25 to 48, 37 to 59, 44 to 67, 14 to 26, 43 to 84 and 9 to 47 at nine, 12, 18.24, 30 and 36 months after planting, respectively.

The per cent growth increase showed that maximum increase was during three to six months period after planting (180 to 217%). The increase was not predominant (14 to 26%) during 18 and 24 months after planting.

Mean values of gbh showed that it was highest, 17.62 cm in A1B3C2 (2 m x 2 m spacing, 40 cm x 40 cm x 40 cm pit size and complete skinning) and the lowest, 13.25 cm in A1B2C3 (2m x 2m spacing, 30 cm x 30 cm x 30 cm pit size and skinning around the plant) treatments.

Analysis of variance showed that there was no significant difference between silvicultural treatments with respect to height at three, six and nine months after planting. But the differences in height were mainly attributable to the highly significant influence of silvicultural treatments at 12, 18, 24, 30 and 36 months after planting. With respect to gbh, the analysis of variance showed nonsignificant difference between silvicultural treatments (Table 3).

The mean volume of trees varied from 0. 2876 x 10^{-2} m^3 in A3B3C3 (3 m x 3 m spacing, 40 cm x 40 cm x 40 cm pit size and skinning around the plant) to 0. 4666 x 10^{-2} m^3 in AIB3C2 (2 m x 2 m spacing, 40 cm x 40 cm x 40 cm pit size and complete skinning) (Table 3). There was considerable difference in the mean volume of trees due to silvicultural treatments.

3.1.2. Nutrient combinations

In the case of different nutrient combinations, trees in N2P2KI treatment had the maximum mean height from nine months after planting. The values were 58.30 cm, 88.57 cm,134.61 cm, 161.65 cm, 250.62 cm and 343.14 cm at nine, 12, 18, 24, 30 and 36 months after planting, respectively (Table 4). In the third and sixth months after planting, maximum height was recorded in N2P3K3 and N2P1K0 treatments, respectively. Corresponding values were 14.32 cm and 42.32 cm.

Table 3. Mean values of tree height, gbh and volume in different silvicultural treatments

Silvicultural treatments*	Periods (months) / height (cm) **								gbh (cm)	Volume ($x\ 10^{-2}m^3$)
	3	6	9	12	18	24	30	36		
$A_1\ B_1\ C_1$	13.61	43.18	54.29	83.92^{a}	121.16^{a}	149.12^{abc}	231.11^{bc}	318.92^{b}	15.04	0.3359
$A_2\ B_3\ C_1$	14.46	41.18	54.97	85.84^{a}	130.74^{cd}	148.79^{ab}	228.64^{b}	320.59^{b}	16.10	0.3735
$A_3\ B_2\ C_1$	14.29	41.60	53.37	77.51^{b}	125.82^{abc}	157.31^{de}	289.40^{e}	316.53^{b}	14.30	0.3102
$A_1\ B_3\ C_2$	12.68	37.54	55.18	84.84^{a}	123.62^{ab}	156.08^{cde}	250.96^{d}	356.16^{e}	17.62	0.4666
$A_2\ B_2\ C_2$	13.36	39.70	54.03	85.83^{a}	128.79^{bcd}	152.22^{bcd}	235.76^{bc}	334.32^{c}	15.31	0.3564
$A_3\ B_1\ C_2$	13.34	39.79	58.51	91.13^{a}	135.62^{d}	165.40^{f}	235.70^{bc}	346.42^{d}	16.92	0.4282
$A_1\ B_2\ C_3$	15.27	42.90	54.20	80.25^{b}	130.88^{cd}	161.63^{ef}	251.78^{d}	334.39^{c}	13.25	0.2901
$A_2\ B_1\ C_3$	14.46	40.67	56.63	77.67^{b}	129.54^{bcd}	148.63^{ab}	236.41^{c}	332.02^{c}	13.79	0.3049
$A_3\ B_3\ C_3$	13.46	38.23	51.58	74.35^{b}	121.06^{a}	143.04^{a}	219.29^{a}	298.34^{a}	13.95	0.2876

* A_1, A_2, and A_3 are 2m x 2m, 2.5m x 2.5m and 3m x 3m spacing; B_1, B_2 and B_3 are pit sizes of 20 cm x 20 cm x 20 cm, 30 cm x 30 cm x 30 cm and 40 cm x 40 cm x 40 cm; C_1, C_2 and C_3 are line, complete and around the plant skinning

** Values superscribed by same letter in one column do not differ significantly

The per cent growth increase was 179 to 200 , 29 to 43, 46 to 54, 50 to 59, 15 to 24, 51 to 59 and 37 to 41 at nine, 12, 18, 24, 30 and 36 months after planting, respectively.

The maximum per cent height increase was observed during three - six months after planting and least at 18 - 24 months. After that, similar to silvicultural treatments, there was a gradual and conspicuous increase in the growth.

Statistical analysis indicated that the difference in tree height was attributable to the highly significant influence of nutrient combinations at nine, 12, 18, 24, 30 and 36 months after planting (Table 4). The N2P2K1 treatment spurred the height even to the level of 15% over control within 36 months after planting.

As regards mean gbh values, the highest value, 18.64cm was found in N2P2K1 and lowest in N0P0K0 (control) treatments. The per cent increase in N2P2KI over N0P0K0 (control) was 20 (Table 4). Analysis of variance showed that there was no significant difference between nutrient combinations with respect to gbh (Table 4).

The interaction between the silvicultural treatments and the nutrient combinations was found to be nonsignificant at each period with respect to height and gbh.

The volume of trees was predicted on the basis of the equation and it varied from 0.3262 x 10^{-2} m^3 in N1P1K3 to 0.4968 x 10^{-2} m^3 in N2P2K1 (Table 4). There was considerable difference in the volume of trees due to nutrient combinations

3.2. Effect of different pit sizes and nutrient combinations on height, gbh and volume of trees in high density planting experiment

3.2.1. Silvicultural treatments

Mean values of tree height at 36 months after planting were 503.75, 446.15 and 463.73 cm in the three pit sizes of 20 cm x 20 cm x 20 cm, 30 cm x 30 cm x 30 cm

and 40 cm x 40 cm x 40 cm, respectively (Table 5). This showed that trees in the pit size of 20 cm x 20 cm x 20 cm had the maximum mean height followed by those in 40 cm x 40 cm x 40 cm and least in 30 cm x 30 cm x 30 cm. The values increased over time and were found to be highest in 20 cm x 20 cm x 20 cm pit size at three, six, nine, 12, 24, 30 and 36 months after planting while at 18^{th} month, it was in 40 cm x 40 cm x 40 cm pit size. They were lowest at three, six, 24, 30 and 36 months after planting in the 30 cm x 30 cm x 30 cm pit size.

With respect to gbh, trees in 20 cm x 20 cm x 20 cm pit size had maximum mean value, 15.34 cm followed by those in 40 cm x 40 cm x 40 cm, 14.54 cm and 30 cm x 30 cm x 30 cm,_13.73 cm (Table 5). This showed that there was not much pronounced effect in gbh due to different pit sizes.

Analysis of variance of data on tree height showed that the differences were mainly due to the significant influence of silvicultural treatments at nine, 12, 18, 24, 30 and 36 months after planting whereas there was no significant difference between the silvicultural treatments with regard to gbh.

The volume of trees predicted on the basis of the equation (Table 5) showed that mean highest volume ($0.4947 \times 10^{-2} m^3$) was in pit size of 20 cm x 20 cm x 20 cm followed by that in 40 cm x 40 cm x 40 cm (0.4241 x 10-2 m3) and least in 30 cm x 30 cm x 30 cm ($0.3766 \times 10^{-2} m^3$).

3.2.2. Nutrient combinations

The amount of fertilisers added/ha in 1 m x 1 m spacing was 4, 6.3 and 9 times of those applied in 2 m x 2 m, 2.5 m x 2.5 m and 3 m x 3 m spacing, respectively. The height and gbh of trees in different nutrient combinations are given in Table 6.

The mean tree height increased along with the period. The mean tree heights were highest in N1P3K0 at three and six months after planting and at 9 and 12 months, they

Table 4. Mean values of tree height, gbh and volume in different nutrient combinations

Nutrient combinations*	Periods (months)/ height (cm)**								gbh (cm)	Volume (x 10^{-2} m^3)
	3	6	9	12	18	4	30	36		
$N_0 P_0 K_0$	13.54	39.07	50.87^{c}	77.49^{b}	123.43^{ab}	147.50^{ab}	227.71^{a}	297.46^{a}	15.54	0.3349
$N_0 P_1 K_2$	14.02	39.89	53.31^{c}	77.80^{b}	122.31^{a}	145.30^{a}	230.55^{ab}	306.75^{cde}	16.12	0.3612
$N_0 P_2 K_3$	13.90	40.38	53.29^{c}	81.05^{b}	127.60^{ab}	154.07^{cdef}	240.73^{de}	327.88^{g}	16.24	0.3845
$N_0 P_3 K_1$	13.64	40.38	53.04^{c}	79.07^{b}	125.30^{ab}	150.95^{bcde}	233.57^{bc}	303.66^{abcd}	15.98	0.3543
$N_1 P_0 K_1$	13.79	41.46	52.98^{c}	80.39^{b}	123.90^{ab}	148.27^{abc}	232.25^{ab}	303.43^{abcd}	15.79	0.3479
$N_1 P_1 K_3$	13.88	40.20	54.19^{b}	83.24^{b}	130.31^{bc}	149.90^{bcd}	226.64^{a}	298.81^{ab}	15.24	0.3262
$N_1 P_2 K_2$	14.24	40.59	55.87^{a}	82.79^{b}	126.57^{ab}	155.45^{defg}	235.90^{bcd}	306.31^{cde}	16.29	0.3672
$N_1 P_3 K_0$	14.16	40.90	55.03^{b}	82.99^{b}	128.70^{ab}	158.68^{fg}	239.61^{cde}	308.32^{de}	16.38	0.3723
$N_2 P_0 K_2$	13.89	40.77	55.24^{b}	82.39^{b}	125.92^{ab}	156.40^{defg}	236.99^{bcd}	304.14^{abcde}	16.02	0.3558
$N_2 P_1 K_0$	13.82	42.32	56.95^{a}	84.92^{a}	130.00^{bc}	154.70^{cdefg}	240.96^{de}	319.11^{f}	16.85	0.3912
$N_2 P_2 K_1$	13.78	41.60	58.30^{a}	88.57^{a}	134.61^{c}	161.65^{g}	250.62^{f}	343.14^{h}	18.64	0.4968
$N_2 P_3 K_3$	14.32	39.60	54.78^{b}	82.32^{b}	123.67^{ab}	151.22^{bcde}	229.44^{ab}	299.90^{abc}	16.00	0.3511
$N_3 P_0 K_3$	13.64	40.09	54.26^{b}	80.79^{b}	125.69^{ab}	151.48^{abcde}	230.19^{ab}	298.94^{ab}	15.92	0.3482
$N_3 P_1 K_1$	13.99	40.30	56.68^{a}	85.83^{a}	131.67^{c}	155.12^{bcdefg}	236.12^{bcd}	305.84^{cde}	16.41	0.3711
$N_3 P_2 K_1$	13.67	40.39	56.00^{a}	83.39^{b}	128.95^{ab}	157.27^{befg}	240.96^{de}	311.23^{e}	17.02	0.3972
$N_3 P_3 K_2$	13.80	40.61	55.24^{b}	84.91^{a}	130.87^{c}	159.31^{bfg}	245.60^{ef}	326.32^{fg}	17.98	0.4499

* N_0, N_1, N_2 and N3 are Nitrogen; P_0, P_1, P_2 and P3 are Phosphorus and K_0, K_1, K_2 and K3 are Potassium each @ 0, 15, 30 and 45 g/plant, respectively.

** Values superscribed by same letter in one column do not differ significantly.

Table 5. Mean values of height, gbh and volume of trees in 1 m x Im spacing under different pit sizes

Pit sizes (cm^3)	Periods (months) /height (cm)*								gbh (cm)	Volume ($x10^{-2}m^3$)
	3	6	9	12	18	24	30	36		
20	14.78	40.90	62.19[b]	119.12[b]	161.42[a]	397.93[c]	471.34c	503.75[c]	15.34	0.4947
30	12.91	34.75	56.30[ab]	10S.20[a]	162.73[a]	289.15[a]	358.56a	446.15[a]	13.73	0.3766
40	14.49	37.02	52.30[a]	99.80[a]	173.18[b]	330.74[b]	374.15b	463.73[b]	14.54	0.4241

were highest in N3P2K1, Thereafter, they were highest in N3P0K3 at 18, 24, 30 and 36 months after planting. The per cent increase in mean tree height varied in various nutrient combinations in different periods and there was no general trend noticed.

The mean gbh value was found to be highest (15.97cm) in N3P0K3 treatment. On a perusal of the results, it was observed that the values in N0P0K0, N1P3K0 and N2P3K3 combinations were very close (14.15 - 14.21 cm) whereas those in N0P1K2, NlP0Kl NIPIK3, N1P2K2, N2P1K0,N3PIK1and N3P3K2 varied slightly from the former three but were very close (14.42 - 14.71 cm).

The gbh values in N0P2K3, N0P3K1, N2P0K2 and N3P2K1 combinations differed from the former two groups; at the same time, they were close (14.75 - 15.01 cm). The values in N2P3KIand N3P0K3 stood aloof from all others (15.90 and 15.97cm).

Analysis of variance of data on tree height and gbh showed that the differences in tree height were mainly attributable to the significant influence of nutrient combinations from 9 months after planting onwards while differences in gbh were not significant (Table 6). The interaction between silvicultural treatments and nutrient combinations was found to be nonsignificant at each period with respect to height and gbh.

The mean volume of trees was predicted on the basis of an equation and it ranged from 0.3933 x 10^{-2} m^3 in control to 0.5869 x 10^{-2} m^3 in N3P0K3 followed by 0.5108 x 10^{-2} m^3 in N2 P0 K2 (Table 6).

3.3. Nutrient contents in different parts of trees

3.3.1. Bolewood

The nutrients *viz.* N, P and K accumulation in bolewood fraction of the representative tree is presented in Tables 7 - 9. Bolewood N was highest, 81 g/tree in A1 B3 C2

(2 m x 2 m spacing, 40 cm x 40 cm x 40 cm pit size and complete skinned plots) and lowest in A1B2C3 (2 m x 2 m spacing; 30 cm x 30 cm x 30 cm pit size and skinning around the plant). The amount of N/ha was 81 g x 2145 trees = 173.75 kg. Bolewood P and K were highest in A2B2C2 (2.5 m x 2.5 m spacing, 30 cm x 30 cm x 30 cm pit size and complete skinned plots) and were 64.2 and 47 g/tree, respectively. Corresponding values for one ha were 82.304 and 60.254 kg.

The total N, P and K contents in A1 B3C2 (2 m x 2 m spacing, 40 cm x 40 cm x 40 cm pit size and complete skinning) in N2P2K1 treatment were 190.40 g. On converting this to hectare basis, it will be 190.40 x 2145 = 408.4089 kg. This revealed that when the tree was harvested and taken away, large amount of N, P and K were removed from the site. As the trees become older, increasing amount of nutrients are incorporated within them. This is due to the increase in dry weight of different parts of the tree. Hence at the end of 7 years, when final felling takes place, the actual amount of nutrients removed from the site will be several times of those removed at the third year. This is with respect to bolewood only

3.3.2. Branches

Nitrogen and P accumulation in branches were highest in A2B2C2 (2.5 m x 2.5 m spacing, 30 cm x 30 cm x 30 cm pit size) and in A1B3C2 (2 m x 2 m spacing, 40 cm x 40 cm x 40 cm pit size), respectively both in completely skinned plots (Appendices I and II). The highest value for N was 30 g/tree 'while for P, it was 12.48g/tree. Corresponding lowest values were 14.0 and 6.3 g/tree in A2BlC3 (2.5 m x 2.5 m spacing; 20 cm x 20 cm x 20 cm pit size and skinning around the plant).

With respect to K, it was found to be highest, 59 g/tree in A1B3C2 (2 m x 2 m spacing, 40 cm x 40 cm x 40 cm pit size and completely skinned plot) and lowest 39 g/tree in A1B1C1 *i.e.* 2 m x 2 m spacing, 20 cm x 20 cm x 20 cm pit size and line skinning (Appendix

Out of the total quantity of branches, quite a large amount will be taken away from the site for fuelwood. Only twigs and very small branches will be left in the site. Hence judicious estimation of how much N, P and K will be removed as well as retained in the site could not be made.

3.3.3. Leaves

Nitrogen and P contents in leaves were highest, 5land 11.2 g/tree in A2B2C2 (2.5 m x 2.5 m spacing and 30 cm x 30 cm x 40 cm pit size) while K accumulation was found to be highest, 78 g/tree in A1B3C2 (2 m x 2 m spacing and 40 cm x 40 cm x 40 cm pit size), all in completely skinned plots (Appendices IV, V & VI).

The lowest values for N, P and K'contents were in A1B1C1 (2 m *x* 2 m spacing, 20 cm x 20 cm x 20 cm pit size and line skinned plots). They were 30 g, 6.0 g and 46.0 g/tree. Converting the highest values to per hectare basis, they were 51 x 2145 = 214.55 kg of N, 11.2 x 1282 = 143. 58 kg of P and 78 x 2145 = 167.31 kg of K. Thus if leaves are retained in the site, considerable amount of N, P and K will be added into the soil through their decomposition.

The nutrients, N, P and K in different parts of the tree were highest in N2P2K1 nutrient combination (Tables 7 - 9 and Appendices I - VI). The relative proportion of the various nutrients differed considerably in different parts of the *tree.* The N accumulation in bolewood was three times that in branches and one and half times that in leaves.

Table 6. Mean values of tree height, gbh and volume in 1 m x 1m spacing under different nutrient combinations

Nutrient combinations*	Periods (months) / height (cm)**								gbh (cm)	Volume ($\times 10^{-2}m^3$)
	3	6	9	12	18	24	30	36		
$N_0 P_0 K_0$	14.05	37.13^{bc}	60.36^{bcd}	105.56^{cde}	159.73^{cd}	299.29^{b}	349.24^{b}	439.86^{a}	14.21	0.3933
$N_0 P_1 K_2$	13.44	31.32^{a}	48.01^{a}	96.30^{ab}	160.71^{cd}	354.96^{de}	412.19^{e}	498.40^{e}	14.42	0.4428
$N_0 P_2 K_3$	14.20	38.85^{bc}	55.83^{bc}	101.02^{bcd}	158.78^{bcd}	359.65^{e}	470.10^{h}	502.12^{e}	14.89	0.4691
$N_0 P_3 K_1$	13.32	39.52^{bc}	59.36^{bcd}	118.30^{ghi}	161.41^{cde}	394.47^{g}	485.26^{i}	521.13^{f}	14.75	0.4529
$N_1 P_0 K_1$	14.67	33.98^{ab}	47.94a	93.10^{a}	154.42^{abc}	289.91^{a}	338.78^{a}	469.10^{bc}	14.59	0.4308
$N_1 P_1 K_3$	14.12	34.41^{ab}	53.40^{ab}	108.26^{def}	158.94^{bcd}	387.77^{g}	439.94^{g}	502.14^{e}	14.71	0.4595
$N_1 P_2 K_2$	13.62	35.81^{abc}	56.61^{bc}	100.78^{bc}	148.75^{a}	394.71^{g}	447.20^{g}	487.96^{d}	14.55	0.4415
$N_1 P_3 K_0$	15.20	41.21^{c}	57.90^{bc}	102.45^{bcde}	151.35^{ab}	343.31^{c}	408.57^{e}	493.90^{de}	14.15	0.4275
$N_2 P_0 K_2$	14.00	36.79^{abc}	57.56^{bc}	105.10^{cde}	149.74^{a}	368.28^{f}	472.09^{h}	548.13^{g}	15.01	0.5108
$N_2 P_1 K_0$	14.09	33.38^{ab}	57.82^{bc}	109.31^{ef}	167.34^{e}	298.26^{b}	358.82^{c}	444.10^{a}	14.55	0.4099
$N_2 P_2 K_1$	13.17	37.81^{bc}	56.70^{bc}	109.74^{ef}	160.15^{cd}	287.27^{a}	346.27^{ab}	439.15^{a}	15.90	0.4677
$N_2 P_3 K_3$	14.02	39.09^{bc}	56.01^{bc}	105.51^{cde}	161.72^{de}	301.47^{b}	373.78^{d}	462.18^{b}	14.21	0.4087
$N_3 P_0 K_3$	13.86	38.40^{bc}	62.03^{cd}	121.06^{hi}	178.92^{f}	402.60^{h}	498.86^{f}	573.14^{h}	15.97	0.5869
$N_3 P_1 K_1$	14.68	37.92^{bc}	60.55^{cd}	113.74^{fgh}	158.13^{bcd}	348.31^{c}	412.86^{e}	488.13^{d}	14.62	0.4462
$N_3 P_2 K_1$	14.46	39.29^{bc}	65.05cd	123.72^{i}	164.36^{de}	351.92^{d}	409.42^{e}	473.06^{c}	14.78	0.4426
$N_3 P_3 K_2$	14.01	35.35^{abc}	55.77^{bc}	114.62^{fgh}	159.92^{cd}	369.15^{f}	427.62^{f}	493.20^{de}	14.71	0.4529

* N0, N1, N2 and N3 are Nitrogen; P0, P1, P2 and P3 are Phosphorus and K0, K1, K2 and K3 are Potassium each @ 0, 15,30 and 45 g/plant, respectively.

** Values superscribed by same letter in one column do not differ significantly

Table 7. Nitrogen accumulation in bolewood (g/tree) in different silvicultural treatments and nutrient combinations

Silvicultural treatments*	Nutrient combinations**															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
$A_1B_1C_1$	43.0	54.0	51.0	52.0	51.0	56.0	52.0	55.0	51.0	45.0	62.0	50.0	57.0	56.0	51.0	55.0
$A_2B_3C_1$	43.0	51.0	55.0	51.0	53.0	51.0	54.0	65.0	52.0	66.0	64.0	56.0	51.0	43.0	52.0	42.0
$A_3B_3C_1$	42.0	54.0	50.0	64.0	51.0	54.0	54.0	54.0	52.0	54.0	65.0	48.0	59.0	55.0	51.0	50.0
$A_1B_3C_2$	49.0	70.0	79.0	72.0	68.0	73.0	78.0	71.0	78.0	60.0	81.0	76.0	76.0	72.0	74.0	70.0
$A_2B_2C_2$	51.0	72.0	62.0	71.0	66.0	75.0	64.0	73.0	75.0	60.0	79.0	66.0	61.0	65.0	71.0	74.0
$A_3B_1C_2$	51.0	50.0	50.0	51.0	52.0	52.0	53.0	51.0	48.0	58.0	61.0	58.0	56.0	50.0	53.0	63.0
$A_1B_2C_2$	41.0	50.0	63.0	64.0	57.0	52.0	62.0	57.0	53.0	58.0	65.0	62.0	64.0	56.0	53.0	50.0
$A_2B_1C_3$	47.0	49.0	57.0	61.0	51.0	52.0	62.0	58.0	56.0	60.0	64.0	52.0	57.0	44.0	47.0	42.0
$A_3B_3C_3$	44.0	53.0	45.0	66.0	56.0	60.0	53.0	56.0	51.0	52.0	59.0	58.0	56.0	56.0	50.0	50.0
1 m x 1m 20 cm^3	47.5	52.0	50.5	48.2	50.4	51.5	52.5	50.0	49.0	50.1	59.5	56.0	49.2	49.7	49.9	50.4
" 30 "	48.8	62.7	67.4	59.4	56.5	63.4	61.6	65.7	63.8	57.2	73.0	56.4	54.4	54.7	61.8	58.1
" 40 "	47.9	60.1	62.8	57.8	55.4	61.6	60.9	63.1	61.7	56.7	68.8	54.9	53.9	51.9	59.6	56.3

* A_1, A_2, and A_3 are 2m x 2 m, 2.5m x 2.5m and 3m x 3m spacing; B_1, B_2 and B_3 are pit sizes of 20 cm x 20 cm x 20 cm, 30 cm x 30 cm x 30 cm and 40 cm x 40 cm x 40 cm; C_1, C_2 and C_3 are line, complete and around the plant skinning .

** 1= N_0 P_0 K_0 ; 2=$N_0P_1K_2$; 3=$N_0P_2K_3$; 4=$N_0P_3K_1$; 5=$N_1P_0K_1$; 6=$N_1P_1K_3$; 7=$N_1P_2K_3$; 8=$N_1P_3K_0$; 9=$N_2P_0K_2$; 10=$N_2P_1K_0$; 11=$N_2P_2K_1$; 12=$N_2P_3K_3$; 13=$N_3P_0K_3$; 14=$N_3P_1K_1$; 15=$N_3P_2K_1$ and 16=$N_3P_3K_2$ where N_0, N_1, N_2 and N_3 are N; P_0, P_1,P_2 and P_3 are P and K_0, K_1, K_2 and K_3 are K @ 0, 15, 30 and 45 g/plant, respectively.

Table 8. Phosphorous accumulation in bolewood (g/tree) in different silvicultural treatments and nutrient combinations

Silvicultural treatments*	Nutrient combinations**															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
$A_1B_1C_1$	27.3	48.1	41.0	44.2	41.6	33.2	35.8	37.7	35.1	32.5	46.8	33.2	44.9	40.3	33.8	35.1
$A_2B_3C_1$	34.5	44.9	41.6	41.6	39.0	48.9	44.9	44.9	49.4	35.1	53.3	43.6	37.1	38.4	41.6	40.1
$A_3B_2C_1$	37.7	33.8	38.4	35.1	42.3	44.9	40.3	37.7	34.5	36.4	54.6	44.2	35.8	36.4	38.4	41.0
$A_1B_3C_2$	40.3	47.5	57.9	57.2	46.8	55.9	57.2	47.5	47.5	55.3	62.4	56.6	53.3	52.0	50.1	53.3
$A_2B_2C_2$	41.6	54.0	54.6	47.5	48.1	50.1	42.9	55.9	47.5	56.6	64.2	49.4	45.5	57.2	50.7	55.9
$A_3B_1C_2$	38.4	45.5	39.7	42.8	50.1	57.9	44.9	43.6	46.2	42.3	63.7	40.3	42.9	50.7	42.9	46.2
$A_1B_2C_3$	35.1	50.1	48.8	46.2	41.6	46.2	41.0	48.8	45.5	49.4	54.6	44.2	41.6	39.7	51.4	50.1
$A_2B_1C_3$	37.1	49.4	42.3	42.3	41.0	43.6	49.4	47.5	43.3	31.1	53.3	41.0	41.0	43.6	44.2	44.9
$A_3B_3C_3$	28.0	50.7	41.6	50.1	39.7	44.2	41.0	44.9	46.2	47.5	53.3	55.9	49.4	41.6	41.2	44.9
1 m x 1m 20 cm^3	36.4	42.3	37.7	41.6	46.2	46.8	39.0	40.3	41.6	37.7	56.6	39.0	38.4	44.2	39.0	41.0
" 30 "	40.3	46.8	41.0	43.6	48.1	47.5	42.3	42.9	43.6	38.4	58.5	42.3	41.6	46.2	47.5	42.3
" 40 "	38.4	44.9	39.7	42.3	48.1	45.5	41.0	42.3	42.3	38.4	57.9	41.6	40.3	42.3	45.5	43.6

* A_1, A_2, and A3 are 2m x 2m, 2.5m x 2.5m and 3m x 3m spacing; B1. B2 and B3 are pit sizes of 20 cm x 20 cm x 20 cm, 30 cm x 30 cm x 30 cm and 40 cm x 40 cm x 40 cm; Cl, C2 and C3are line, complete and around the plant skinning.

** 1=N_0P_{0K0}; 2=$N_0P_1K_2$; 3=$N_0P_2K_3$; 4=$N_0P_3K_1$;5=$N_1P_0K_1$; 6=$N_1P_1K_3$; 7=$N_1P_2K_3$; 8=$N_1P_3K_0$; 9=$N_2P_0K_2$;10=$N_2P_1K_0$; 11=$N_2P_2K_1$;12=$N_2P_3K_3$;13=$N_3P_0K_3$; 14=$N_3P_1K_1$; 15=$N_3P_2K_1$ and 16=$N_3P_3K_2$ where N_0, N_1, N_2 and N3 are N; P_0, P_1, P_2 and P3 are P and K_0, K_1, K_2 and K_3 are K @ 0, 15.30and 45g/plant, respectively.

Table 9. Potassium accumulation in bolewood (g/tree) in different silvicultural treatments and nutrient combinations

Silvicultural treatments*	Nutrient combinations**															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
$A_1B_1C_1$	8.0	12.0	14.0	12.0	10.0	13.0	12.0	14.0	15.0	14.0	25.0	12.0	13.0	13.0	12.0	14.0
$A_2B_3C_1$	10.0	14.0	11.0	**11.0**	13.0	10.0	17.0	11.0	11.0	18.0	30.0	11.0	14.0	11.0	11.0	17.0
$A_3B_2C_1$	**10.0**	13.0	14.0	11.0	14.0	14.0	12.0	11.0	12.0	19.0	133.0	13.0	**11.01**	17.01	14.01	11.0
$A_1B_3C_2$	18.0	34.0	32.0	33.0	29.0	32.0	31.0	30.0	31.0	33.0	45.0	34.0	30.0	30.0	34.0	32.0
$A_2B_2C_2$	17.0	36.0	31.0	35.0	34.0	34.0	34.0	37.0	34.0	33.0	47.0	38.0	33.0	34.0	33.0	35.0
$A_3B_1C_2$	18.0	21.0	29.0	25.0	27.0	24.0	20.0	28.0	29.0	21.0	34.0	24.0	23.0	22.0	23.0	24.0
$A_1B_2C_3$	11.0	15.0	18.0	17.0	15.0	16.0	17.0	15.0	18.0	19.0	29.0	19.0	16.0	15.0	18.0	16.0
$A_2B_1C_3$	12.0	14.0	10.0	13.0	11.0	12.0	13.0	13.0	10.0	11.0	29.0	16.0	14.0	14.0	10.0	15.0
$A_3B_3C_3$	14.0	12.0	12.0	21.0	7.0	21.0	12.0	21.0	23.0	21.0	34.0	21.0	11.0	21.0	24.0	18.0
1 m x 1 m 20 m^3	16.0	18.0	20.0	21.0	21.0	16.0	18.0	20.0	21.0	20.0	31.0	21.0	22.0	19.0	18.0	22.0
" 30 "	18.0	31.0	26.0	31.0	30.0	28.0	27.0	29.0	28.0	30.0	38.0	31.0	30.0	29.0	27.0	30.0
" 40 "	17.0	27.0	23.0	29.0	28.0	25.0	26.0	25.0	24.0	28.0	35.0	29.0	27.0	24.0	24.0	28.0

* A_1, A_2, and A3 are 2m x 2m, 2.5m x 2.5m and 3m x 3m spacing; B_1, B_2 and B3 are pit sizes of 20 cm 20 cm x 20 cm, 30 cm x 30 cm x 30 cm and 40 cm x 40 cm x 40 cm; C_1, C_2 and C3 are line, complete and around **the** plant skinning **.**

** 1= N_0 P_0 K_0 ; 2=$N_0P_1K_2$; 3=$N_0P_2K_3$; 4=$N_0P_3K_1$; 5=$N_1P_0K_1$; 6=$N_1P_1K_3$; 7=$N_1P_2K_3$; 8=$N_1P_3K_0$; 9=$N_2P_0K_2$; 10=$N_2P_1K_0$; 11=$N_2P_2K_1$;12=$N_2P_3K_3$; 13=$N_3P_0K_3$; 14=$N_3P_1K_1$; 15=$N_3P_2K_1$ and 16=$N_3P_3K_2$ where N_0, N_1, N_2 and N3 are N; P_0,P_1,P_2 and P3 are P and K_0, K_1, K_2 and K3 are K @ 0, 15,30 and 45 g/plant, respectively.

3.4. Multilocational trials

3.4.1. Soils in the experimental plots at Punalur and Kottappara

3.4.1.1. Punalur

The soils in the Punalur experimental plots were sandy loam in the surface and loamy sand in deeper layers (Table 1). They were slightly acidic in the surface and sub surface layers and medium acidic in the 40-60 cm layer. Organic carbon contents were low and the ratios of organic carbon: total N were 24.67, 16.20 and 17.33 in the three layers, *viz.* 0-20,20-40 and 40-60 cm, respectively.

3.4.1.2. Kottappara

With respect to soils in the experimental plots at Kottappara, they were loamy sand and slightly acidic in all layers (Table 1). Organic carbon contents were low and the ratios of organic carbon: total N were 15.07, 15.33 and 16.75 in the 0-20, 20-40 and 40-60 cm layers, respectively. The available P contents were very low and K status was relatively higher both at Punalur and Kottappara throughout the soil profile.

3.4.2. Effect of different silvicultural treatments and nutrient combinations on height

The results of the multilocational trials at Punalur and Kottappara are depicted in Tables 10 and 11, respectively. The multilocational trials were carried out on the basis of the results of one year study at Vallakkadavu. The observations at Vallakkadavu during the periods three, six, nine and 12 months after planting showed that among the silvicultural treatments, A1B3C2 (2 m x 2 m spacing, 40 cm x 40 cm x 40 cm pit size and complete skinning), A2B2C2 (2.5 m x 2.5 m spacing, 30 cm x 30 cm x 30 cm pit size and complete skinning), A2B3C1(2.5 m x 2.5 m spacing, 40 cm x 40 cm x 40 cm pit size and line skinning) and A3B1C2 (3 m x 3

spacing, 20 cm x 20 cm x 20 cm pit size and complete skinning) were found to be the best whereas the best nutrient combination was N2P2K1. In order to have detailed statistical evaluation, the following nutrient combinations were tested at the multilocational trials. They were NlPlK0 NlP1K2, N1P3K0, NlP3K2, N3P1K0, N3P1K2 N3P3K0, and N3P3K2.

3.4.2.1. Punalur

It was observed that there was a gradual increase in the tree height in the different silvicultural treatments and nutrient combinations at Punalur (Table 10). Trees in AlB3C2 (2 m x 2 m spacing, 40 cm x 40 cm x 40 cm pit size and complete skinned) showed maximum height till 24 months after planting while in the case of nutrient combinations, it was in NlPlK0 at six months after planting and in NlP1K2 at 12 and 24 months after planting. Analysis of variance revealed that there was no significant difference between the silvicultural treatments and nutrient combinations with respect to tree height.

3.4.2.2. Kottappara

The results at Kottappara manifested that trees in AlB3C2 (2 m x 2 m spacing, 40 cm 40 cm x 40 cm pit size and complete skinned) had the maximum height after six months while it was in A2B3C1 (2.5 m x 2.5 m spacing, 40 cm x 40 cm x 40 cm pit size and line skinned) after 12 and 24 months of planting (Table 11). With respect to nutrient combinations, the trees in N3PlK2, N3P3K2 and N3P3K0 had maximum height after six, 12 and 24 months, respectively. Analysis of variance showed that the differences in tree height were not significant due to silvicultural treatments and fertiliser combinations.

The multilocational trials revealed that trees more or less responded similarly to various silvicultural treatments. Also, those treatments found most suitable for *E. grandis* were equally suitable for *E. tereticornis* at lower elevations. In other words,

the observations on *E. grandis* in the grasslands of Vallakkadavu can be transferred to *E. tereticornis* at lower elevations under different agroclimatic conditions.

3.5. Cost of planting

3.5.1. Vallakkadavu

The cost of planting/ha for different silvicultural treatments and nutrient combinations for two years are shown in Table 12 and Appendices VII & VIII. The cost for planting operations is divided into pre-planting, post planting in the first year and the total for the two years. For pre-planting, the cost/ha varied from Rs. 3429/- in A3B3 C3 (3 m x 3 m spacing, 40 cm x 40 cm x 40 cm pit size and skinning around plant) to Rs.5035/- in A1B3C2 (2 m x 2 m spacing, 40 cm x 40 cm x 40 cm pit size and complete skinning). For post-planting, the cost varied from Rs 4875/- in A3B1C2 (3 m x 3 m spacing, 20 cm x 20 cm x 20 cm pit size and complete skinning) to Rs. 6910/- in A1BlCl (2 m x 2 m spacing, 20 cm x 20 cm x 20 cm pit size and line skinning).

The planting cost for the two years was highest, Rs. 9460/- in A1B1C1 (2 m x 2 m, 20 cm x 20 cm x 20 cm and line skinning, followed by Rs. 9035/- in AIB2C2 (2 m x 2 m spacing, 30 cm x 30 cm x 30 cm pit size and skinning around the plant). The lowest expenditure Rs. 6100/- was in A3B1C2 (3 m x 3 m spacing, 20 cm x 20 cm x 20 cm pit size and complete skinning) (Appendix VII).

The cost for different nutrient combinations for three applications alone vaned from 0 paise for N0P0K0 to 407.20 paise for N2P3K3 (Appendix VIII). In the case of 2 m x 2 m, 2.5 mx 2.5 m, 3 m x 3 m, corresponding values for one hectare were Rs. nil in all the control plots to Rs.10180/-, Rs. 6515.20, and Rs. 4523.99, respectively.

Table 10. Mean values of tree height (cm) in different silvicultural treatments and nutrient combinations at Punalur

Silvicultural treatments*/ Periods	Tree height(cm)	Nutrient combinations**/ Tree height (cm)							
		$N_1P_1K_0$	$N_1P_1K_2$	$N_1P_3K_0$	$N_1P_3K_2$	$N_3P_1K_0$	$N_3P_1K_2$	$N_3P_3K_0$	$N_3P_3K_2$
After six months		64.20	62.50	56.90	59.00	64.00	62.80	60.20	60.10
$A_1B_3C_2$	70.30								
$A_2B_2C_2$	62.62								
$A_2B_3C_1$	59.89								
$A_3B_1C_2$	52.03								
After 12 months		86.40	94.40	79.20	81.20	89.80	90.50	85.40	86.10
$A_1B_3C_2$	100.40								
$A_2B_2C_2$	89.10								
$A_2B_3C_1$	83.00								
$A_3B_1C_2$	74.20								
After 24 months		131.20	141.50	122.30	125.80	134.20	137.20	130.60	128.60
$A_1B_3C_2$	149.60								
$A_2B_2C_2$	133.40								
$A_2B_3C_1$	126.40								
$A_3B_1C_2$	116.20								

* A_1, A_2, and A_3 are 2m x 2m, 2.5m x 2.5m and 3m x 3m spacings; B_1 B_2 and B_3 are pit sizes of 20 cm x 20 cm x 20 cm, 30cm x 30cm x 30cm and 40 cm x 40 cm x 40 cm and C_1 and C_2 are line and complete skinning.

** N_1 and N_3 are N @ 15 & 45 g/plant; P_1 and P_3 are P @ 15 & 45 g/plant; K_0 and K_2 are K @ 0 & 30 g/plant.

Table 11. Mean values of tree height (cm) in different silvicultural treatements and nutrient combinatations at Kottappara

Silvicultural treatments*	Tree height(cm)	Nutrient combination**/Tree height (cm)							
		$N_1P_1K_0$	$N_1P_1K_2$	$N_1P_3K_0$	$N_1P_3K_2$	$N_3P_1K_0$	$N_3P_1K_2$	$N_3P_3K_0$	N3P3K2
After six months		74.20	74.00	72.70	73.10	73.60	77.90	71.90	73.00
$A_1B_3C_2$	77.00								
$A_2B_2C_2$	74.00								
$A_2B_3C_1$	70.50								
$A_3B_1C_2$	70.10								
After 12 months		89.80	87.90	90.70	90.40	92.50	94.80	96.10	98.30
$A_1B_3C_2$	84.30								
$A_2B_2C_2$	97.50								
$A_2B_3C_1$	102.40								
$A_3B_1C_2$	99.50								
After 24 months		153.80	153.60	160.00	158.90	163.30	164.70	166.00	162.70
$A_1B_3C_2$	128.80								
$A_2B_2C_2$	172.50								
$A_2B_3C_1$	172.60								
$A_3B_1C_2$	171.00								

* A1, A2, and A3 are 2m x 2m, 2.5m x 2.5m and 3m x 3m spacings; B1, B2 and B3 are pit sizes of 20 cm x 20cm x 20 cm, 30 cm x 30cm x 30cm and 40 cm x 40 cm x 40 cm and C1 and C2 are complete and skinning.

** N1 and N3 are N @ 15 & 45 g/plant; Pi and P3 are P @ 15 & 45 g/plant;K0 and K2 are K @ 0 & 30

Table 12. Total cost of planting/ha for different silvicultural treatments and nutrient combinations

Silvicultural treatments*	Nutrient combinations**/ cost (Rs./ha)															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
$A_1 B_1 C_1$	9460	13256	15904	15108	11726	15522	15874	15078	15078	13990	13196	15844	19640	16258	15462	16962
$A_2 B_3 C_1$	8119	10548	12243	11734	9569	11999	12224	11715	11018	10510	12205	14634	12471	11960	12920	14615
$A_3 B_2 C_1$	7903	9590	10767	10413	8910	10597	10753	10400	9916	9563	10740	12427	10925	10570	11237	12414
$A_1 B_3 C_2$	8012	11808	14456	13660	10278	14074	14426	13630	12542	11748	14396	18192	14810	14014	15594	18162
$A_2 B_2 C_2$	6888	9137	11012	10503	8338	10768	10993	10484	9787	9280	10974	13403	11240	10729	11689	13384
$A_3 B_1 C_2$	6100	7787	8964	18610	7107	8794	8950	8597	8113	7760	8937	10624	9122	8767	9434	10611
$A_1 B_2 C_3$	9035	12831	15479	14683	11301	15097	15449	14653	13565	12771	15419	19215	15833	15037	16537	19185
$A_2 B_1 C_3$	8139	10568	12263	11754	9589	12011	12244	11735	11038	10530	12225	14654	12491	11960	12940	14635
$A_3 B_3 C_3$	7847	9534	10711	10357	8854	10511	10697	10344	9860	9507	10684	12371	10869	10514	11181	12358
1 m x 1m 20cm^3	13076	28260	38852	35668	22140	37324	38732	35548	31196	28020	38612	53796	40274	37084	38492	53676
30	14076	29260	39852	36668	23140	38324	39737	36548	32196	29020	39612	54796	41274	38084	39492	54676
40	15076	28260	40852	37668	24140	39334	40732	37548	33196	30020	40612	55796	42274	39084	40492	55676

* A_1, A_2, and A_3 are 2m x 2m, 2.5m x 2.5m and 3m x 3m spacings; B_1, B_2 and B_3 are pit sizes of 20 cm x 20 cm x 20 cm, 30 cm x 30 cm x 30 cm and 40 cm x 40 cm x 40 cm; C_1, C_2 and C_3 are line, complete and around the plant skinning .

** 1=$N_0P_0K_0$; 2=$N_0P_1K_2$; 3=$N_0P_2K_3$; 4=$N_0P_3K_1$; 5=$N_1P_0K_1$; 6=$N_1P_1K_3$; 7=$N_1P_2K_2$; 8=$N_1P_3K_0$; 9=$N_2P_0K_2$;10=$N_2P_1K_0$; 11= $N_2P_2K_1$; 12=$N_2P_3K_3$; 13= $N_3P_0K_3$; 14= $N_3P_1K_1$; 15=$N_3P_2K_1$ and 16= $N_3P_3K_2$ where N_0, N_1, N_2 and N_3 are N; P_0, P_1, P_2 and P_3 are P and K_0, K_1, K_2 and K_3 are K @ 0, 15, 30 and 45 g/plant, respectively.

The total cost for different silvicultural treatments and nutrient combinations (Table 12) showed that the treatment N3P0K3 in A1B1C1 (2 m x 2 m spacing, 20 cm x 20 cm x 20 cm pit size and line skinning) required maximum cost (Rs. 19,640/-) and the least, Rs. 6100/- was for N0P0K0 in A3B1C2 (3 m x 3 m, 20 cm x 20 cm x 20 cm, complete skinning). In nutshell, the cost varied considerably and the effectiveness of the treatment can be arrived at only through evaluation of the volume produced and the cost incurred for production.

3.5.2. High density planting experiment

The cost of planting/ha for 1 m x 1m spacing are shown in Table 12 and Appendices VII and VII. Similar to cost of planting at Vallakkadavu, the cost of planting/ha in 1 m x 1m spacing showed that it varied from Rs. 10,000/- in 20 cm x 20 cm x 20 cm pit size to Rs. 12,000/- in 40 cm x 40 cm x 40 cm pit size for pre-planting. The planting cost/ha for the first year were Rs. 11,988/- for 20 cm x 20 cm x 20 cm, while for 30 cm x 30 cm x 30 cm and for 40 cm x 40 cm x 40 cm x 40cm pit sizes, the costs were Rs. 12988/- and Rs.13,988/-, respectively.

With respect to planting cost/ha for the two years, they were Rs.13,076/-, Rs.14,076/- and Rs. 15,076/- for 20 cm x 20 cm x 20 cm, 30 cm x 30 cm x 30 cm and 40 cm x 40 cm x 40 cm pit sizes, respectively. It could thus be seen that there was considerable difference in the cost between three different pit sizes. With respect to cost/ha of different nutrient combinations, it varied from 0 for control to Rs. 40720/- in N2P3K3 treatment. The total cost for planting/ha also varied considerably. It was found to be lowest, Rs. 13,076/- in the control in 20 cm x 20 cm x 20 cm pit size and the highest, Rs. 55,796/- was in N2P3K3 combination in 40 cm x 40 cm x 40 cm pit size. The per cent increase in cost in the highest was 327 over the lowest one.

Comparison of total cost for planting in 2 m x 2 m, 2.5 m x 2.5 m, 3 m x 3 m and 1 m x 1 m spacing under the same silvicultural treatments revealed that there was

considerable difference in the total cost. It varied from 207 to about 327% in the 1 m x 1 m spacing when compared with other spacings.

3.6. Relative treatment effectiveness (RTE)

3.6.1. Vallakkadavu

The RTE values are shown in Table 13. There was no pattern for the RTE values. The values varied from -12.97 in A2B2C2 (2.5 m x 2.5 m spacing, 30 cm x 30 cm x 30 cm pit size and skinning complete) to 79.78.87 in A1B1C1 (2 m x 2 m spacing, 20 cm x 20 cm x 20 cm pit size and line skinned). In the line skinned plots, the RTE values were higher in 2 m x 2 m spacing and 20 cm x 20 cm x 20 cm pit size (AIBI) while in the complete skinned plots, they. were higher n 3 m x 3 m spacing and 20 cm x 20 cm x 20 cm pit size (A3B1). In the skinning around the plants, the values were higher in 2.5 m x 2.5 m and 20 cm x 20 cm x 20 cm pit size (A2 B2).

The RTE values were relatively higher in the line skinned plots than in the other two silvicultural treatments. As regards pit sizes, 20 cm x 20 cm x 20 cm pit size had relatively higher RTE values. With respect to nutrient combinations, the RTE values were found to be relatively higher in the N2P2KIcombination. Among the 16 nutrient combinations and nine silvicultural treatments, N2P2Kl nutrient combination and 20 cm x 20 cm x 20 cm pit size and line skinned silvicultural treatments were found to give relatively higher RTE values.

3.6.2. High density planting experiment

The RTE values in 1 m x 1 m spacing and under three pit sizes of 20 cm x 20 cm x 20 cm, 30 cm x 30 cm x 30 cm and 40 cm x 40 cm x 40 cm revealed that they varied from -6.60 in 40 cm x 40 cm x 40 cm to 56.46 in 20 cm x 20 cm x 20 cm. They were higher in 30 cm x 30 cm x 30 cm, 40 cm x 40 cm x 40 cm when compared with

Table 13. Relative treatment effectiveness (RTE) of different silvicultural treatments and nutrient combinations

Silvicultural treatments*	Nutrient combinations**														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
$A_1B_1C_1$	23.97	39.78	13.14	13.87	12.41	36.08	29.73	36.17	37.01	79.78	15.22	14.45	60.60	68.08	68.34
$A_2B_3C_1$	15.08	22.73	1.16	0.32	3.00	19.17	20.28	18.34	30.78	54.54	29.68	50.70	14.28	26.02	29.38
$A_3B_2C_1$	-1.57	18.11	15.67	11.09	-1.10	-12.89	10.74	-2.10	11.17	33.48	-0.13	-11.90	6.86	3.06	21.80
$A_1B_3C_2$	17.17	23.69	23.63	7.06	-1.10	18.77	16.27	8.69	41.02	39.78	17.70	24.16	4.01	13.63	35.08
$A_2B_2C_2$	3.41	-3.67	2.86	-9.10	-12.97	12.12	6.08	3.43	6.14	19.29	2.25	-1.16	1.17	12.81	6.47
$A_3B_1C_2$	25.39	16.73	1.90	2.52	2.84	15.67	24.75	10.80	21.05	71.27	17.98	1.68	15.19	26.73	4.70
$A_1B_2C_3$	8.97	3. 64	-7.06	7.79	4.98	25.68	6. 98	6.35	24.72	52.62	2.98	22.66	21.60	41.37	38.15
$A_2B_1C_3$	9.85	22.62	44.20	37.52	17.24	15.93	27.47	28.67	26.89	67.01	13.88	15.63	23.48	29.13	57.16
$A_3B_3C_3$	3.99	16.43	29.24	-5.30	-11.23	11.72	8. 21	4.65	18.67	41.92	3.41	-0.70	31.81	1.20	16.83
1 m x 1m 20 cm^3	4.48	13.31	17.86	16.68	13.20	9.61	13.10	35.27	0.97	9.85	0.57	56.46	11.40	9.45	13.34
30	33.17	20.83	19.40	2.24	18.95	16.20	16.60	21.31	6.20	11.02	5.89	47.55	13.74	13.01	11.77
40	3.69	25.11	26.64	10.01	19.57	13.20	-6.60	37.53	8.56	0.29	5.69	45.61	15.68	15.91	21.98

* A_1, A_2, and A_3 are 2m x 2m, 2.5m x 2.5m and 3m x 3m spacings; B_1, B_2 and B_3 are pit sizes of 20 cm x 20 cm x 20 cm, 30 cm x 30 cm x 30 cm and 40 cm x 40 cm x 40 cm; C_1, C_2 and C_3 are line, complete and around the plant skinning .

** 1= $N_0P_1K_2$; 2= $N_0P_2K_3$; 3= $N_0P_3K_1$; 4= $N_1P_0K_1$; 5= $N_1P_1K_3$; 6= $N_1P_2K_2$; 7= $N_1P_3K_0$; 8= $N_2P_0K_2$; 9 = $N_2P_1K_0$; 10= $N_2P_2K_1$; 11= $N_2P_3K_3$; 12= $N_3P_0K_3$;13= $N_3P_1K_1$;14=$N_3P_2K_1$ and 15= $N_3P_3K_2$ where N_0, N_1, N_2 and N_3 are N; P_0, P_1, P_2 and P_3 are P and K_0, K_1, K_2 and K_3 are K @ 0, 15, 30 and 45 g/plant, respectively.

20 cm x 20 cm x 20 cm (Table 13). Among 30 cm x 30 cm x 30 cm and 40 cm x 40 cm x 40 cm pit sizes, RTE values were relatively higher in 40 cm x 40 cm x 40 cm. With respect to nutrient combinations, it was found that the values were very high in N3P0K3 combination in all pit sizes.

3.6.3. Comparison of RTE values in different spacings

On a comparison of RTE values in the 2 m x 2 m, 2.5 m x 2.5 m and 3 m x 3 m spacings and those in 1 m x 1 m spacing in complete skinned plots in the respective pit sizes, it could be seen that the values in 3 m x 3 m, were higher than those in 1 m x 1 m while in the other two spacings the RTE values were lower than those in 1 m x 1 m spacings. The highest value was recorded in N2P2K1 nutrient combination in 3 m x 3 m, 2.5 m x 2.5 m and 2 m x 2 m spacings while in the 1 m x 1 m spacing it was in N3P0K3 nutrient combination.

3.7. Relative economic effectiveness (REE)

3.7.1. Vallakkadavu

The REE values varied from 0.08 to 57.19, the former in A3B2C1 (3 m x 3 m spacing, 30 cm x 30 cm x 30 cm pit size and line skinning) and the latter in the A1B1C1 (2 m x 2 m spacing, 20 cm x 20 cm x 20 cm pit size and line skinned) in the N2P3K3 and N2P2K1 nutrient combinations, respectively (Table 14). In the line skinned treatment, the values were relatively higher in 2 m x 2 m spacing and 20 cm x 20 cm x 20 cm pit size while in completely skinned treatment, they were found to be relatively higher in 3 m x 3 m spacing and 20 cm x 20 cm x 20 cm pit size. With regard to skinning around the plant treatment, the REE values were higher in 2.5 m x 2.5 m spacing in 20 cm x 20 cm x 20 cm pit size.

It could be seen that the REE values were, in general, higher in A1B1C1 (2 m x 2 m spacing, 20 cm x 20 cm x 20 cm pit size and line skinned treatment). With respect to

pit sizes, the values in 20 cm x 20 cm x 20 cm had relatively higher REE values than those in 30 cm x 30 cm x 30 cm and 40 cm x 40 cm x 40 cm pit sizes in all spacings and skinning operations. The values were, in general, higher in the line skinned plots when compared with those in the complete skinned and skinning around the plant plots. The values in N2P2K1 combination in all spacing, pit sizes and skinning recorded the highest values.

3.7.2. High density planting experiment

The REE values in the high density planting experiment in 1 m x 1 m spacing are given in Table 14. They ranged from -2.65 in 40 cm x 40 cm x 40 cm pit size in N1P3K0 to 18.33 in 20 cm x 20 cm x 20 cm pit size in N3P0K3. The values in 40 cm x 40 cm x 40 cm pit size were relatively higher than those in other two pit sizes. They were relatively lower in 20 cm x 20 cm x 20 cm pit size than those in 30 cm x 30 cm x 30 cm. The values in N3P0K3 combination were found to record the maximum in all the three pit sizes followed by N2P0K2 combination.

3.8. Comparison of REE values in different spacings

On a comparison of REE values in the completely skinned plots in 2 m x 2 m, 2.5 m x 2.5 m, 3 m x 3 m and 1 m x 1 m spacings, it was seen that they were higher in N2P2K1treatment in the former three and in N3P0K3 in the latter. It was also found that they were higher in 2 m x 2 m, 2.5 m x 2.5 m and 3 m x 3m spacings when compared with 1 m x 1 m in the respective pit sizes. It showed that 2 m x 2 m, 2.5 m x 2.5 m and 3 m x 3 m were relatively better with respect to REE.

Among 2 m x 2 m, 2.5 m x 2.5 m and 3 m x 3 m spacings, 3 m x 3 m was found to be relatively better with respect to RTE and REE values. It could thus be inferred that N2P2K1 was the most effective nutrient combination with regard to economics while spacing of 3 m x 3 m, pit size of 20 cm x 20 cm x 20 cm and line skinned treatments were the most effective silvicultural treatments.

Table 14. Relative economic effectiveness (REE) of different silvicultural treatments and nutrient combinations

Silvicultural treatments*	Nutrient combinations**														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
$A_1B_1C_1$	17.11	123.66	8.23	11.19	7.56	21.50	18.65	122.69	25.02	57.19	9.09	6.96	35.26	41.65	38.11
$A_2B_3C_1$	11.61	15.07	0.80	0.27	2.03	12.73	14.05	13.51	23.78	36.28	16.47	33.01	9.69	16.35	16.32
$A_3B_2C_1$	1.29	13.29	11.89	9.84	0.82	9.47	8.16	1.67	9.23	24.64	0.08	8.61	5.13	2.15	13.88
$A_1B_3C_2$	11.65	13.13	13.86	5.50	0.63	10.42	9.56	5.55	27.97	22.14	7.79	13.07	2.29	7.00	15.48
$A_2B_2C_2$	20.15	2.30	1.88	7.52	8.30	7.59	3.99	2.41	4.56	12.11	1.16	0.71	0.75	7.55	3.33
$A_3B_1C_2$	19.89	11.38	0.62	2.16	1.97	10.68	17.56	8.12	16.55	48.65	10.32	1.12	10.57	17.28	2.70
$A_1B_2C_3$	6.32	2.12	4.34	6.23	2.98	15.02	4.30	4.23	17.49	30.83	1.40	12.93	12.98	22.60	17.97
$A_2B_1C_3$	7.59	15.01	37.52	31.85	11.68	10.59	19.05	21.14	20.78	44.61	7.71	10.18	15.98	18.32	31.79
$A_3B_3C_3$	3.28	12.04	22.15	4.70	8.38	8.60	6.23	3.70	15.41	30.79	2.16	0.51	23.74	0.84	10.69
1 m x lm 20 m^3	2.07	4.48	6.55	9.85	4.62	3.24	4.82	14.78	0.45	3.34	0.14	18.33	4.02	3.21	3.25
30	15.96	7.36	7.45	1.36	6.96	5.74	6.39	9.32	3.01	3.92	1.51	16.62	5.22	4.76	3.09
40	1.97	9.27	10.66	6.25	7.50	4.89	-2.65	7.04	19.36	3.82	1.54	16.27	6.01	5.92	5.95

* A_1, A_2, and A3 *are* 2m x 2m, 2.5m1x 2.5m and 3m x 3m spacings; B_1, B_2 and B_3 are pit sizes of 20cmx 20cmx 20 cm, 30 cm x 30 cm x 30 cm and 40 cm x 40 cm x 40 cm; C_1, C_2 and C3 are line, complete and around the plant skinning.

** 1= N_0 P_1K_2; 2= N_0 P_2K_3; 3= N_0 P_3K_1; 4=N_1 P_0K_1; 5= $N_1P_1K_3$; 6=$N_1P_2K_2$; 7= $N_1P_3K_0$; 8= N_2 P_0 K_2; 9 = $N_2P_1K_0$; 10= $N_2P_2K_1$;11=$N_2P_3K_3$; 12=$N_3P_0K_3$;13= $N_3P_1K_1$;14=$N_3P_2K_1$ and 15=$N_3P_3K_2$ where N_0, N_1, N_2 and N3 are N; P_0, P_1, P_2 and P3 **are** P and K_0, K_1, K_2 and K3 **are** K @ 0, 15, 30 and 45 g/plant, respectively.

3.9. Comparison of height, gbh and volume of trees in various spacings

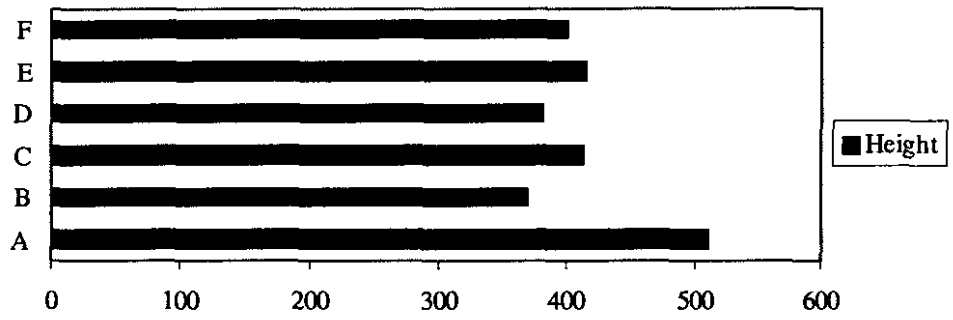
The study was a comparative evaluation of different silvicultural treatments and nutrient combinations taken together on height and gbh and hence volume of trees. A comparison of the mean height, gbh and volume of trees due to the same nutrient treatment, N2P2K1, in different spacings subject to the same silvicultural treatment *viz.* line skinning in different pit sizes of 20 cm x 20 cm x 20 cm, 30 cm x 30 cm x 30 cm and 40 cm x 40 cm x 40 cm is given in Fig. 3.

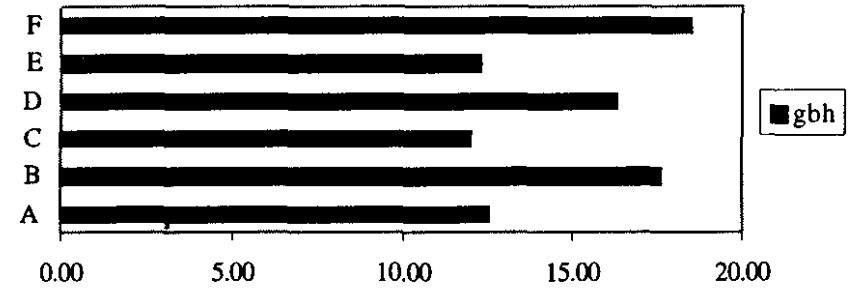
The number of trees/ha in 1 m x lm, 2 m x 2 m, 2.5 m x 2.5 rn and 3 m x 3 m were 8122, 2145, 1282 and 866, respectively at the end of the experiment. These included the caualties replaced during the second year. When they were excluded, the corresponding numbers were 7915, 1986, 1041 and 738. The effective spacing at the end of three years was 1.11 m x 1.11 m for 1 m x 1 m, 1.15 m x 2.15 m for 2 m x 2 m, 2.8 m x 2.8 m for 2.5 m x 2.5 m and 3.4 m x 3.4 m for 3 m x 3 m spacing.

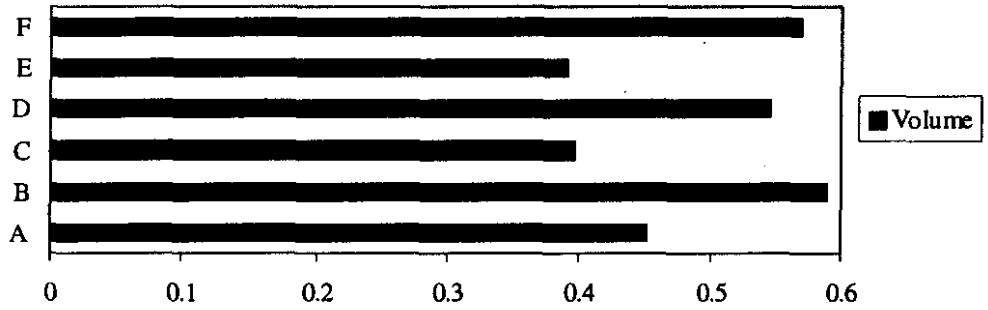
The maximum height of trees, 510.25 cm was observed in 1 m x l m spacing and 20 cm x 20 cm x 20 cm pit size. This was followed by those 1 m x lm spacing and 40 cm x 40 cm x 40 cm pit size and then in lm x Im spacing and 30 cm x 30 cm x 30 cm pit size, 413.71 and 412.45 cm, respectively. The lowest value, 370.31 cm was found in 3 m x 3 m spacing and 20 cm x 20 cm x 20 cm pit size.

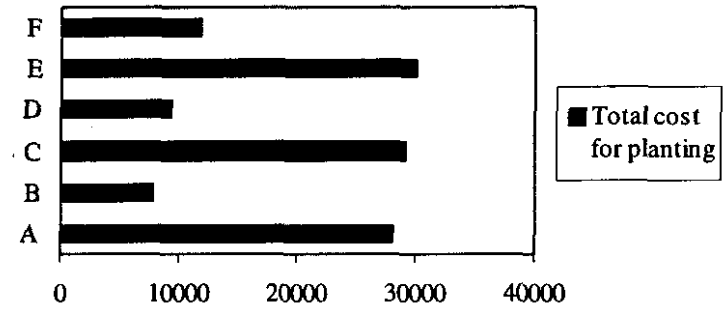
With respect to gbh, the lowest 12.01 cm value was recorded in 1 m x 1 m spacing and 30 cm x 30 cm x 30 cm pit size while the highest 18.52 cm was in 2 m x 2 m spacing and 40 cm x 40 cm x 40 cm pit size. The gbh values in 1 m x 1 m in all pit sizes had lower values when compared with 2 m x 2 m, 2.5 m x 2.5 m and 3 m x 3 m spacing.

As regards volume, the highest value, 0.5895 x 10^{-2} m^3 was in 3 m x 3 m spacing and 20 cm x 20 cm x 20 cm pit size followed by 2 m x 2 m spacing and 40 cm x 40 cm x 40 cm pit size, 0.5687 x 10^{-2} m^3. The lowest value was in 1 m x 1 m and 30 cm x









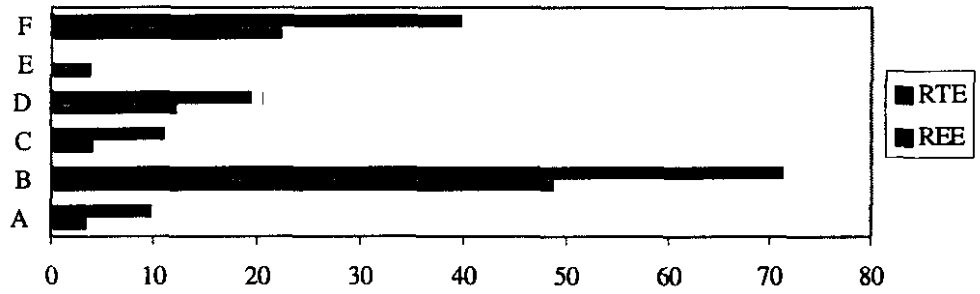


Fig: 3. Height (cm), gbh (cm), volume of trees (x 10^{-2} m^3), cost of planting (Rs./-), RTE and REE values in $N_2P_2K_1$ nutrient combination in complete skinned plots under different spacings

A	1 m x 1 m ; 20 cm x 20 cm x 20 cm
B	3 m x 3 m ; „
C	1 m x 1 m ; 30 cm x 30 cm x 30 cm
D	2.5 m x 2.5 m ; „
E	1 m x 1 m ; 40 cm x 40 cm x 40 cm
F	2 m x 2 m ; „

30 cm x 30 cm pit size, 0.3965 x 10^{-2} m^3. The lower values for volume in 1 m x 1 m spacing agrees with the findings of Ola Adams (1993) who reported that wider spacing was different from other spacings in terms of volume of trees.

The quantity of fertilisers added /ha in I m x 1 m, 2 m x 2 m, 2.5 m x 2.5 m and 3 m x 3 m spacings were 2608.00, 652.00, 417.28 and 289.75 kg of Urea; 6000.00, 1500.00, 960.00 and 666.60 kg of Mussorie rock phosphate and 1154.00, 288.50, 184.64 and 128.21 kg of Muriate of potash, respectively. In otherwords, the amount of fertlisers added /ha in 1 m x lm spacing was 4, 6,and 9 times of that applied in 2 m x 2 m, 2.5 m x 2.5 m and 3 m x 3 m spacing, respectively.

The RTE values in the above treatments revealed that they were considerably lower in 40,20 and 30 cm^3 pit sizes in 1 m x 1 m spacing . The highest, 71.27 was recorded in 3 m x 3 m spacing and 20 cm x 20 cm x 20 cm pit size. When REE values were compared, it could be seen that the values were very low in pit sizes in 1 m x 1 m spacing. The highest, 48.65 was found in 3 m x 3 m spacing and 20 cm x 20 cm x 20 cm pit size.

The results revealed that among different spacings, trees in 3 m x 3 m spacing and 20 cm x 20 cm x 20 cm pit size had highest RTE and REE values and yielded relatively more volume. On economic and yield basis 3 m x 3 m spacing and 20 cm x 20 cm x 20 cm pit size silvicultural treatment was found to be most effective. Among the different skinning operations, line skinning was observed to be relatively better.

The results on the effect of application of fertilizers on the growth of eucalypts corroborate the findings of Bonny (1991), Kane *et a1* (1992), Qureshi and Yadav (1967) Schonau (1983), Valeri et al (l993) and Wilkins (1990). The lower values for gbh in 1 m x 1 m spacing may be due to the closer spacing and this supports the observations of Chauhan *et a1* (1983).

The uptake of N, P, and K and yield manifested that the trees responded maximum to a particular treatment *viz.,* N2P2K1 in all pit sizes, skinning operations and wider spacings (2 m x 2 m, 2.5 m x 2.5 m and 3 m x 3 m). This supports the finding of Miller (1981) who proposed that prior to canopy closure, tree growth was very dependent on nutrients from the soil and growth responses to nutrients can be expected. The uptake also showed that eucalypts is not only a heavy absorber of nutrients but also as a species which retains much of what it absorbs, thus placing a high demand on soil nutrient resources.

Considering the effect of different nutrient combinations, it was observed that the trees in N2P2KI *ie.*, 30 g Nitrogen, 30 g Phosphorous and 15 g Potassium /plant was found beneficial for increasing the volume. This is equivalent to 65 g of Urea, 150 g of Mussori rock phosphate and 29 g of Muriate of potash /plant for one application in the first year. On converting to per ha in 3 m x 3 m spacing, the quantities of fertilizers required were 72.438 kg of Urea, 166.650 kg of Mussori rock phosphate and 31.108 kg of Muriate of potash. The total cost for the fertilisers for the first and second years for three applications was Rs. 2837.05. Thus by applying N2P2KI nutrient combination at the time of planting, during north- east monsoon period in the first year and during south - west monsoon period in the second year with double the dose of that applied in the first year, it was possible to increase the height, gbh and hence volume of trees.

The results are on the basis of observations for the first three years. In order to establish the best treatment combinations, height and gbh of trees will have to be continuously monitored till the tree is finally felled at the rotation period of seven years.

The study indicated that during the years prior to canopy closure, tree growth was very much dependent on the current uptake of nutrients. In other words, the trees fertilised overtook the unfertilised trees during the periods of response. In the long run, the treated trees are expected to produce more volume than unfertilised trees. It is

obvious that application of fertilisers is costly and therefore required to be investigated on economic ground. It should be emphasized that the present situation is such that food production has been increased several times but there is not sufficient raw materials for cooking and for paper and pulp industries etc. Hence it would be wiser to consider application of fertilisers as part of integrated management for maximising productivity.

4. CONCLUSIONS

The conclusions are on the basis of observations for the first three years. The study revealed that

1. the height, gbh and volume of eucalypts **(** *E.grandis* and *E. tereticornis)* were found to be influenced by different silvicultural tretments such as spacing, pit sizes and skinning and by fertiliser applications
2. between different spacings, pit sizes and skinning operations, the trees in 3 m x 3 m spacing, 20cm x 20 cm x 20 cm pit size and line skinned were found to have maximum height, gbh and volume
3. among the different nutrient combinations, $N_2P_2K_1$ *ie.,* application of N @ 30 g, P @ 30 g and K @ 15 g /plant or 65 g urea, 150 g Mussorie rock phosphate and 29 g muriate of potash /plant at the time of planting, during north- east monsoon in the first year and double the dose during south- west monsoon period was found to increase the height and gbh significantly.
4. the bolewood retained considerable amount of nutrients. The quantity of nutrients in bolewood was two times of that in branches and one and half times of that in leaves.
5. it is a heavy absorber of nutrients and retains most of what it absorbs
6. in order to establish the best treatment combinations, height and gbh of trees will have to be continuously monitored till the trees are finally felled at the rotation period of seven years and the volume/biomass estimated.

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APPENDIX I

Nitrogen accumulation in branches (g/tree) in different silvicultural treatments and nutrient combinations

Silvicultural treatments*	Nutrient combinations**															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
$A_1B_1C_1$	15.0	18.0	20.0	17.0	17.0	18.0	19.0	20.0	19.0	19.0	22.0	20.0	18.0	18.0	17.0	16.0
$A_2B_3C_1$	19.0	20.0	21.0	19.0	20.0	20.0	20.0	22.0	19.0	21.0	23.0	20.0	22.0	19.0	20.0	20.0
$A_3B_2C_1$	18.0	19.0	19.0	20.0	19.0	20.0	20.0	19.0	19.0	20.0	23.0	20.0	21.0	21.0	20.0	21.0
$A_1B_3C_2$	22.0	25.0	25.0	26.0	24.0	26.0	26.0	25.0	26.0	25.0	30.0	26.0	24.0	24.0	25.0	25.0
$A_2B_2C_2$	22.0	25.0	26.0	23.0	24.0	26.0	25.0	27.0	28.0	29.0	30.0	28.0	25.0	24.0	27.0	23.0
$A_3B_1C_2$	20.0	23.0	24.0	24.0	22.0	23.0	23.0	26.0	25.0	24.0	27.0	23.0	25.0	23.0	24.0	23.0
$A_1B_2C_3$	18.0	21.0	21.0	21.0	19.0	21.0	22.0	19.0	20.0	20.0	25.0	21.0	19.0	22.0	21.0	20.0
$A_2B_1C_3$	14.0	19.0	21.0	19.0	19.0	19.0	21.0	22.0	20.0	20.0	23.0	20.0	20.0	22.0	19.0	21.0
$A_3B_3C_3$	19.0	20.0	21.0	20.0	22.0	21.0	21.0	20.0	20.0	20.0	25.0	21.0	21.0	24.0	22.0	22.0
1 m x 1m 20cm^3	18.0	17.0	19.0	20.0	18.0	18.0	19.0	20.0	19.0	18.0	21.0	19.0	19.0	18.0	18.0	19.0
" 30 "	21.0	24.0	25.0	24.0	22.0	23.0	25.0	22.0	24.0	23.0	28.0	25.0	26.0	25.0	24.0	23.0
" 40 "	19.0	21.0	23.0	23.0	20.0	20.0	22.0	21.0	22.0	21.0	25.0	23.0	24.0	22.0	22.0	21.0

* A_1, A_2, and A_3 are 2m x 2m, 2.5m x 2.5m and 3m x 3m spacings; B_1, B_2 and B_3 are pit sizes of 20cm x 20cm x 20 cm, 30 cm x 30 cm x 30 cm and 40 cm x 40 cm x 40 cm; C_1, C_2 and $C_3$are line, complete and around the plant skinning .

** 1=$N_0P_0K_0$ 2=$N_0P_1K_2$; 3=$N_0P_2K_3$; 4=$N_0P_3K_1$; 5=$N_1P_0K_1$; 6=$N_1P_1K_3$; 7=$N_1P_2K_2$; 8=$N_1P_3K_0$; 9=$N_2P_0K_2$; 10=$N_2P_1K_0$; 11=$N_2P_2K_1$; 12=$N_2P_3K_3$; 13=$N_3P_0K_3$; 14=$N_3P_1K_1$; 15=$N_3P_2K_1$ and 16=$N_3P_3K_2$ where N_0, N_1, N_2 and N3 are N P_0,P_1,P_2 and P3 are P and K_0, K_1, K_2 and K3 are K @ 0, 15, 30 and 45 g/plant, respectively.

APPENDIX II

Phosphorous accumulation in branches (g/tree) in different silvicultural treatments and nutrient combinations

Silvicultural treatments*	Nutrient combinations**															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
$A_1B_1C_1$	7.2	7.8	7.2	7.8	7.8	7.2	7.2	9.1	7.8	8.5	7.8	7.2	7.8	8.5	7.2	6.5
$A_2B_3C_1$	6.5	8.5	8.5	7.2	7.8	7.8	7.8	8.5	7.8	7.8	9.1	8.5	7.2	7.2	7.8	7.2
$A_3B_2C_1$	6.5	8.5	8.5	7.2	7.8	7.2	7.8	7.8	7.2	7.2	9.8	7.8	7.8	7.8	7.2	7.8
$A_1B_3C_2$	7.8	10.4	11.1	11.1	9.8	10.4	11.7	11.1	10.4	11.1	12.4	10.4	9.8	10.4	10.4	9.8
$A_2B_2C_2$	7.8	10.4	10.4	11.1	9.8	11.1	10.4	11.1	10.4	11.1	12.4	9.8	9.8	11.1	10.4	9.8
$A_3B_1C_2$	7.2	9.1	9.8	7.8	8.5	10.4	8.5	9.8	9.1	8.5	11.1	9.1	8.5	8.5	8.5	7.2
$A_1B_2C_3$	7.2	9.1	9.1	7.2	8.5	8.5	7.8	8.5	9.1	7.2	10.4	8.5	7.8	8.5	7.8	7.2
$A_2B_1C_3$	6.3	7.2	7.8	8.5	7.8	7.8	7.8	7.2	7.8	8.5	9.1	8.5	7.8	7.2	7.8	7.8
$A_3B_3C_3$	6.5	8.5	7.8	9.1	8.5	7.8	7.8	8.5	8.5	9.1	10.4	7.2	8.5	8.5	7.8	7.8
1 m x 1m 20 cm^3	7.2	7.2	7.8	7.2	7.2	7.8	7.2	7.8	7.2	7.8	9.1	7.8	7.2	7.8	7.2	7.2
" 30 "	7.2	7.8	7.2	8.5	7.2	7.8	7.8	7.2	7.8	7.8	10.4	7.8	7.8	8.5	7.8	7.8
" 40 "	7.2	7.2	7.2	7.2	7.8	7.2	7.2	7.8	7.2	7.2	9.8	7.8	7.8	7.8	7.8	7.8

* A1. A2, and A3 are 2 m x 2 m, 2.5 m x 2.5 m and 3 m x 3 m spacing; B1, B2 and B3 are pit sizes of 20 cm x 20 cm x 20 cm, 30 cm x 30 cm x 30 cm and 40 cm x 40 cm x 40 cm; C1, C2 and C3 are line, complete and around the plant skinning.

** 1=$N_0P_0K_0$ 2=$N_0P_1K_2$; 3=$N_0P_2K_3$; 4=$N_0P_3K_1$; 5=$N_1P_0K_1$; 6=$N_1P_1K_3$; 7=$N_1P_2K_2$; 8=$N_1P_3K_0$; 9=$N_2P_0K_2$; 10=$N_2P_1K_0$; 11=$N_2P_2K_1$; 12=$N_2P_3K_3$; 13=$N_3P_0K_3$; 14=$N_3P_1K_1$; 15=$N_3P_2K_1$ and 16=$N_3P_3K_2$ where N_0, N_1, N_2 and N3 are N ; P_0,P_1,P_2 and P3 are P and K_0, K_1, K_2 and K3 are K @ 0, 15, 30 and 45 g/plant, respectively.

APPENDIX III

Potassium accumulation in branches (g/tree) in different silvicultural treatments and nutrient combinations

Silvicultural treatments*	Nutrient combinations**															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
$A_1B_1C_1$	39.0	43.0	40.0	44.0	41.0	42.0	43.0	44.0	41.0	42.0	46.0	43.0	41.0	42.0	41.0	40.0
$A_2B_3C_1$	44.0	45.0	48.0	44.0	47.0	46.0	45.0	48.0	49.0	47.0	41.0	45.0	48.0	46.0	49.0	47.0
$A_3B_2C_1$	44.0	43.0	44.0	45.0	44.0	45.0	46.0	45.0	44.0	45.0	47.0	43.0	42.0	46.0	44.0	46.0
$A_1B_3C_2$	50.0	53.0	54.0	56.0	53.0	54.0	55.0	56.0	54.0	55.0	51.0	59.0	54.0	57.0	56.0	55.0
$A_2B_2C_2$	51.0	51.0	55.0	55.0	52.0	53.0	54.0	54.0	53.0	56.0	50.0	57.0	57.0	56.0	57.0	55.0
$A_3B_1C_2$	48.0	50.0	51.0	52.0	50.0	51.0	53.0	51.0	49.0	51.0	54.0	51.0	51.0	51.0	49.0	51.0
$A_1B_2C_3$	46.0	47.0	50.0	49.0	48.0	49.0	50.0	48.0	49.0	53.0	53.0	49.0	48.0	49.0	49.0	50.0
$A_2B_1C_3$	46.0	47.0	47.0	49.0	48.0	48.0	48.0	49.0	46.0	49.0	50.0	48.0	46.0	48.0	48.0	47.0
$A_3B_3C_3$	46.0	50.0	51.0	50.0	48.0	51.0	50.0	50.0	51.0	50.0	52.0	47.0	49.0	50.0	51.0	51.0
1 m x 1m 20 cm^3	43.0	44.0	46.0	46.0	45.0	43.0	45.0	44.0	44.0	45.0	52.0	44.0	44.0	45.0	44.0	44.0
" 30 "	46.0	46.0	49.0	49.0	48.0	45.0	47.0	46.0	47.0	40.0	47.0	47.0	45.0	49.0	49.0	48.0
" 40 "	44.0	45.0	47.0	48.0	46.0	44.0	45.0	44.0	45.0	47.0	45.0	45.0	44.0	47.0	46.0	45.0

* A1, A2, and A3 are 2m x 2m, 2.5m x 2.5m and 3m x 3m spacings; B1, B2 and B3 are pit sizes of 20 cm x 20 cm x 20 cm, 30 cm x 30 cm x 30 cm and 40 cm x 40 cm x 40 cm; C1. C2 and C3 are line, complete and around the plant skinning .

** 1=$N_0P_0K_0$ 2=$N_0P_1K_2$; 3=$N_0P_2K_3$; 4=$N_0P_3K_1$; 5=$N_1P_0K_1$; 6=$N_1P_1K_3$; 7=$N_1P_2K_2$; 8=$N_1P_3K_0$; 9=$N_2P_0K_2$; 10=$N_2P_1K_0$; 11=$N_2P_2K_1$; 12=$N_2P_3K_3$; 13=$N_3P_0K_3$; 14=$N_3P_1K_1$; 15=$N_3P_2K_1$ and 16=$N_3P_3K_2$ where N_0, N_1, N_2 and N3 are N P_0,P_1,P_2 and P3 are P and K_0, K_1, K_2 and K3 are K @ 0, 15, 30 and 45 g/plant, respectively.

APPENDIX IV

Nitrogen accumulation in leaves (g/tree) in different silvicultural treatments and nutrient combinations

Silvicultural treatments*	Nutrient combinations**															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
$A_1B_1C_1$	30.0	33.0	35.0	34.0	32.0	35.0	37.0	34.0	36.0	32.0	40.0	34.0	32.0	36.0	36.0	35.0
$A_2B_3C_1$	31.0	36.0	34.0	36.0	34.0	34.0	34.0	34.0	34.0	34.0	41.0	34.0	34.0	33.0	35.0	34.0
$A_3B_2C_1$	31.0	35.0	35.0	34.0	33.0	36.0	35.0	34.0	36.0	33.0	42.0	35.0	33.0	37.0	35.0	34.0
$A_1B_3C_2$	37.0	45.0	42.0	47.0	43.0	46.0	47.0	44.0	43.0	43.0	49.0	42.0	45.0	46.0	45.0	44.0
$A_2B_2C_2$	38.0	45.0	43.0	44.0	42.0	46.0	45.0	44.0	45.0	42.0	51.0	41.0	45.0	45.0	44.0	46.0
$A_3B_1C_2$	37.0	38.0	41.0	41.0	38.0	39.0	41.0	41.0	39.0	36.0	45.0	36.0	37.0	39.0	39.0	40.0
$A_1B_2C_3$	31.0	36.0	37.0	37.0	35.0	34.0	34.0	37.0	36.0	33.0	43.0	34.0	38.0	36.0	36.0	36.0
$A_2B_1C_3$	32.0	34.0	34.0	35.0	34.0	36.0	34.0	34.0	34.0	34.0	40.0	36.0	35.0	36.0	36.0	36.0
$A_3B_3C_3$	33.0	34.0	36.0	36.0	36.0	39.0	37.0	34.0	36.0	37.0	42.0	34.0	35.0	38.0	35.0	38.0
1 m x 1m 20 cm^3	32.0	34.0	37.0	35.0	35.0	34.0	36.0	36.0	34.0	33.0	40.0	33.0	31.0	33.0	33.0	34.0
" 30 "	35.0	37.0	38.0	41.0	36.0	36.0	39.0	38.0	37.0	39.0	45.0	40.0	38.0	36.0	38.0	35.0
" 40 "	33.0	35.0	37.0	38.0	34.0	35.0	37.0	36.0	36.0	38.0	43.0	39.0	37.0	35.0	36.0	34.0

* A1, A2, and A3 are 2m x 2m, 2.5m x 2.5m and 3m x 3m spacing; B1, B2 and B3 are pit sizes of 20cm x 20cm x 20 cm, 30 cm x 30 cm x 30 cm and 40 cm x 40 cm x 40 cm; C1, C2 and C3are line, complete and around the plant skinning.

** 1=$N_0P_0K_0$ 2=$N_0P_1K_2$; 3=$N_0P_2K_3$; 4=$N_0P_3K_1$; 5=$N_1P_0K_1$; 6=$N_1P_1K_3$; 7=$N_1P_2K_2$; 8=$N_1P_3K_0$; 9=$N_2P_0K_2$; 10=$N_2P_1K_0$; 11=$N_2P_2K_1$; 12=$N_2P_3K_3$; 13=$N_3P_0K_3$; 14=$N_3P_1K_1$; 15=$N_3P_2K_1$ and 16=$N_3P_3K_2$ where N_0, N_1, N_2 and N3 are N ; P_0,P_1,P_2 and P3 are P and K0, K1, K2 and K3 are K @ 0, 15.30 and 45 respectively.

APPENDIX V

Phosphorous accumulation in leaves (g/tree) in different silvicultural treatments and nutrient combinations

Silvicultural treatments*	Nutrient combinations**															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
$A_1B_1C_1$	6.0	6.5	7.2	7.2	7.2	7.2	7.2	6.5	6.5	7.2	7.2	6.5	6.5	6.5	7.2	7.2
$A_2B_3C_1$	6.5	7.2	7.8	7.8	7.8	7.2	7.2	6.5	7.2	6.5	7.8	7.8	7.8	7.2	7.2	7.2
$A_3B_2C_1$	6.5	7.2	6.5	6.5	7.2	7.8	7.2	6.5	6.5	7.2	7.2	7.2	6.5	6.5	6.5	7.2
$A_1B_3C_2$	7.2	10.4	9.8	9.8	9.8	9.1	9.8	9.8	9.1	10.4	11.1	9.1	9.8	9.1	9.8	11.1
$A_2B_2C_2$	7.8	9.8	10.4	9.1	8.5	9.1	10.4	9.1	10.4	9.8	11.2	9.8	10.4	9.8	10.4	10.4
$A_3B_1C_2$	7.2	7.8	7.8	8.5	8.5	7.8	8.5	8.5	8.5	8.5	9.8	7.8	8.5	7.8	7.8	7.8
$A_1B_2C_3$	7.2	7.8	7.2	6.5	7.2	7.8	7.8	7.2	7.2	7.2	8.5	7.8	7.2	7.8	7.8	7.2
$A_2B_1C_3$	7.2	7.8	7.2	7.2	7.2	7.8	7.8	7.2	6.5	7.2	7.8	7.2	7.2	7.2	7.2	6.5
$A_3B_3C_3$	6.5	8.5	7.8	7.2	7.2	7.8	7.8	7.8	7.8	7.8	9.1	7.8	7.2	7.8	7.2	7.2
1 m x 1m 20 cm^3	6.5	7.2	7.2	7.8	7.8	7.8	7.2	7.2	7.8	7.8	9.1	7.2	7.2	7.8	7.2	7.2
" 30 "	7.2	8.5	9.1	8.5	7.8	8.5	9.1	8.5	9.1	8.5	10.4	8.5	9.8	8.5	8.5	7.8
40	7.2	7.8	8.5	7.8	7.2	7.8	8.5	7.8	8.5	9.1	9.8	9.1	8 5	9.1	8.5	8.5

* A1. A2, and A3 are 2 m x 2 *m,* 2.5 m x 2.5 mand 3 m x 3 m spacing; B1. B2 and B3 are pit sizes of 20 cm x 20 cm x 20 cm, 30 cm x 30 cm x 30 cm and 40 cm x 40 cm x 40 cm; C1. C2 and C3are line, complete and around the plant skinning.

** $1=N_0P_0K_0$ $2=N_0P_1K_2$; $3=N_0P_2K_3$; $4=N_0P_3K_1$; $5=N_1P_0K_1$; $6=N_1P_1K_3$; $7=N_1P_2K_2$; $8=N_1$ P3 K_0; $9=N_2P_0K_2$; $10=N_2P_1K_0$; where $11=N_2P_2K_1$; $12=N_2P_3K_3$; $13=N_3P_0K_3$; $14=N_3P_1K_1$; $15=N_3P_2K_1$ and $16=N_3P_3K_2$ where No, N_1, N_2 and N3 are N P_0,P_1,P_2 and P3 are P and K_0, K1. K2 and K3 are K @ 0, 15,30 and 45 g/plant, respectively.

APPENDIX VI

Potassium accumulation in leaves (g/tree) in different silvicultural treatments and nutrient combinations

Silvicultural treatments*	Nutrient combinations**															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
$A_1B_1C_1$	46.0	51.0	51.0	51.0	51.0	51.0	51.0	51.0	51.0	45.0	54.0	47.0	52.0	51.0	46.0	51.0
$A_2B_3C_1$	50.0	52.0	55.0	55.0	55.0	51.0	51.0	54.0	55.0	54.0	57.0	52.0	52.0	53.0	51.0	51.0
$A_3B_2C_1$	49.0	51.0	52.0	52.0	52.0	50.0	52.0	51.0	51.0	51.0	56.0	50.0	53.0	53.0	54.0	51.0
$A_1B_3C_2$	64.0	69.0	73.0	69.0	71.0	72.0	67.0	74.0	68.0	73.0	78.0	74.0	68.0	73.0	74.0	65.0
$A_2B_2C_2$	65.0	75.0	74.0	72.0	70.0	74.0	66.0	69.0	67.0	72.0	77.0	72.0	68.0	73.0	73.0	69.0
$A_3B_1C_2$	63.0	70.0	67.0	69.0	06.0	66.0	67.0	67.0	68.0	69.0	74.0	68.0	67.0	67.0	65.0	69.0
$A_1B_2C_3$	61.0	62.0	62.0	61.0	64.0	65.0	62.0	63.0	66.0	64.0	66.0	61.0	66.0	60.0	62.0	61.0
$A_2B_1C_3$	54.0	58.0	57.0	56.0	55.0	58.0	57.0	56.0	54.0	57.0	62.0	57.0	57.0	56.0	58.0	56.0
$A_3B_3C_3$	59.0	65.0	63.0	62.0	63.0	64.0	65.0	62.0	66.0	64.0	64.0	62.0	61.0	61.0	63.0	63.0
1 m x 1m 20 cm^3	41.0	50.0	58.0	59.0	48.0	54.0	57.0	57.0	51.0	63.0	73.0	60.0	61.0	58.0	56.0	57.0
" 30 "	43.0	52.0	56.0	57.0	49.0	53.0	59.0	52.0	53.0	65.0	75.0	63.0	64.0	59.0	59.0	58.0
" 40 "	42.0	53.0	54.0	61.0	50.0	54.0	56.0	54.0	52.0	61.0	71.0	62.0	62.0	63.0	57.0	51.0

* A1. A2, and A3 are 2m x 2m, 2.5m x 2.5m and 3m x 3m spacing; B1, B2 and B3 are pit sizes of 20 cm x 20 cm x 20 cm, 30 cm x 30 cm x 30 cm and 40 cm x 40 cm x 40 cm; C1. C2 and C3 are line, complete and around the plant skinning.

****1=$N_0P_0K_0$ 2=$N_0P_1K_2$; 3=$N_0P_2K_3$; 4=$N_0P_3K_1$; 5=$N_1P_0K_1$; 6=$N_1P_1K_3$; 7=$N_1P_2K_2$; 8=$N_1P_3K_0$; 9=$N_2P_0K_2$; 10=$N_2P_1K_0$; 11=$N_2P_2K_1$; 12=$N_2P_3K_3$;13=$N_3P_0K_3$; 14=$N_3P_1K_1$; 15=$N_3P_2K_1$ and 16=$N_3P_3K_2$ where N_0, N_1, N_2 and N3 are N; P_0,P_1,P_2 and P3 are P and K_0, K_1, K_2 and K3 are K @ 0, 15, 30 and 45 g/plant, respectively.**

APPENDIX VII

Cost of plantingiha for *E grandis* at Vallakkadavu

Operations	Silvicultural treatments*											
	$A_1B_1C_1$	$A_1B_2C_3$	$A_2B_1C_3$	$A_2B_2C_2$	$A_3B_2C_1$	$A_1B_3C_2$	$A_3B_1C_2$	$A_3B_3C_3$	$A_2B_3C_1$	1 m x 1m		
										$20cm^3$	$30cm^3$	$40cm^3$
(A) Pre-planting												
1. Raising seedlings	1250	1250	800	800	556	1250	556	556	800	4000	4000	4000
(Rs. 1250/2500)												
2. Clear knife weeding in	500	500	500	375	500	375	375	500	500	375	375	375
April 1992 (Rs. 500/ha)												
3. Collection of sticks	100	100	125	125	135	100	135	135	125	100	100	100
for alignment												
4. Cost of alignment	245	245	315	315	350	245	350	350	315	210	210	210
5. Collection of pegs @ 8ps	200	200	128	128	89	200	89	89	125	800	800	800
6. Labour cost for lay-out	350	350	420	420	455	350	455	455	420	280	280	280
7. Pitting	500	750	320	480	333	1000	220	444	480	2000	3000	4000
8. Transport of seedlings	240	240	300	300	360	240	360	360	300	160	160	160
9. Cost of planting	400	400	370	370	340	400	340	340	370	1200	1200	1200
10. Skinning	825	450	288	875	367	875	875	200	528	875	875	875
Total	4610	4485	3566	4188	3485	5035	3755	3429	3546	10000	11000	12000
(B) Post-planting												
1. Knife weeding in Oct'92	375	375	375	188	375	188	188	375	375	188	188	188
2. Spade weeding in Oct'92	500	500	500	250	500	250	250	500	500	---	---	---
3. Knife weeding in Jan'93	375	375	375	188	375	188	188	375	375	---	---	---
4. Spade weeding in Jan'93	500	500	500	250	500	250	250	500	500	---	---	---
B Total	1750	1750	1750	876	1750	876	876	1750	1750	188	188	188

contd..

(C) Cost of applying fertiliser	400	400	256	256	178	400	178	178	256	1200	1200	1200
Aldrex.(30EC) and application	150	150	96	96	66	150	66	66	96	600	600	600
Total	550	550	352	352	244	550	244	244	352	1800	1800	1800
Total for Ist Year	**6910**	**6785**	**5668**	**5416**	**5479**	**6461**	**4875**	**5423**	**5648**	**11988**	**12988**	**13988**
IInd Year												
1. Knife weeding in May 1993	500	500	500	375	500	375	375	500	500	188	188	188
(Rs. 500/ha)												
2. Knife weeding in Oct. '93	375	375	375	188	375	188	188	375	375	---	---	---
3. spade weeding in Oct. '93	500	500	500	250	500	250	250	500	500	---	---	---
4. Knife weeding in Jan. '94	375	375	375	188	375	188	188	375	375	---	---	---
5. Spade weeding in Jan. '94	500	500	500	250	500	250	250	500	500	---	---	---
6. Cost of applying fertiliser	200	200	128	128	89	200	89	89	128	600	600	600
7. Casuality replacement	100	100	93	93	85	100	85	85	93	300	300	300
Total	**2550**	**2250**	**2471**	**1472**	**2424**	**1551**	**1425**	**2424**	**2471**	**1088**	**1088**	**1088**
Grand Total	**9460**	**9035**	**8139**	**6888**	**7903**	**8012**	**6100**	**7847**	**8119**	**13076**	**14076**	**15076**

* **A1, A2, and A are 2m x 2m. 2.5m x 2.5m and 3m x 3m spacings; B1.B2 and B3 are pit sizes of 20 cm x 20 cm x 20 cm; 30 cm x 30 cm x 30 cm and 40 cm x20 cm x 40 cm and C1, and C3 are line, complete and around the plant skinning.**

APPENDIX VIII

Cost of planting/ha due to different silvicultural treatments and nutrient combinations

Treatments*	Cost/plant	Cost(Rs.)/ha in different spacings**			
	(Ps.)	2m x 2m	2.5m x 2.5m	3m x 3m	1m x1m
$N_0P_0K_0$	0	0	0	0	0
$N_0P_1K_2$	151.84	3796	2429.44	1686.94	15184.00
$N_0P_2K_3$	257.76	6444	4124.16	2863.71	25776.00
$N_0P_3K_1$	225.92	5648	3614.72	2509.97	22592.00
$N_1P_0K_1$	90.64	2266	1450.24	1007.01	9064.00
$N_1P_1K_3$	242.48	6062	3879.68	2693.95	24248.00
$N_1P_2K_2$	256.56	6414	4104.96	2850.38	25656.00
$N_1P_3K_0$	224.72	5618	3595.52	2496.64	22472.00
$N_2P_0K_2$	181.20	4530	2899.20	2013.13	18120.00
$N_2P_1K_0$	149.44	3736	2391.04	1660.28	14944.00
$N_2P_2K_1$	255.36	6384	4085.76	2837.05	25536.00
$N_2P_3K_3$	407.20	10180	6515.20	4523.99	40720.00
$N_3P_0K_3$	271.98	6798	4351.68	3021.69	27198.00
$N_3P_1K_1$	240.08	6002	3841.28	2667.29	24008.00
$N_3P_2K_0$	300.08	7502	4801.28	3333.89	25416.00
$N_3P_3K_2$	406.00	10150	6496.00	4510.66	40600.00

* No, N1, N2 and N3 are N; P0,P1,P2 and P3 are P and K0, K1, K2 and K3 are K at 0, 15,30 and 45 g/plant, respectively.

** For 2,500 plants in 2m x 2m spacing
For 1,600 plants in 2.5m x 2.5m spacing
For 1,111 plants in 3m x 3m spacing
For 10,000 plants in 1 m x 1m spacing