COMPARATIVE PERFORMANCE OF THREE EXOTIC TREE SPECIES IN SOCIAL FORESTRY STRIP PLANTING IN TRICHUR SOCIAL FORESTRY DIVISION

BY
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THESIS
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DEDICATED TO MY PARENTS

DECLARATION

I hereby declare that the thesis entitled "COMPARATIVE PERFORMANCE OF THREE EXOTIC TREE SPECIES IN SOCIAL FORESTRY STRIP PLANTING IN TRICHUR SOCIAL FORESTRY DIVISION" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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CERTIFICATE

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ABBREVIATIONS

CANP	Current Annual Net Production
cm	Centimetre
C/N Ratio	Carbon/Nitrogen Ratio
c.o.	Casual Organism
DBH; dbh	Diameter at breast height
Fa	Family
FAO	Food and Agricultural Organisation
GBH, gbh	Girth and breast height
Ha	Hectare
HDEP	High Density Energy Plantation
Ht	Height
K	Potash
Kg	Kilogramme
m	Metres
m^3	Cubic metres
MABI	Mean annual biomass increment
MADI	Mean annual diameter increment
MAHI	Mean annual height increment
MAI	Mean annual increment
MANP	Mean annual net production
mm	millimetre
mt	metric tonne
N	Nitrogen
P	Phosphorus
ppm	parts per million
sp., spp.	Species
Sub Fa	Sub family
Syn	Synonym
Temp	Temperature

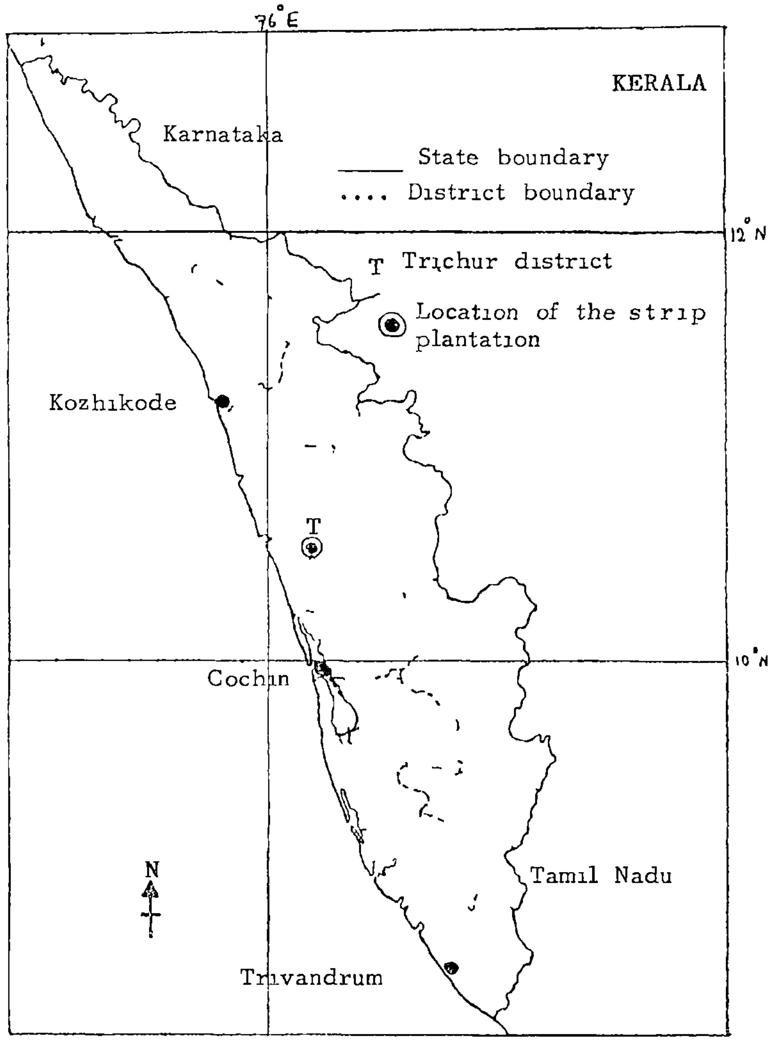
INTRODUCTION

1. INTRODUCTION

The twentieth century witnessed enormous destruction of natural forests either due to the unplanned exploitation of the resources or due to the allotment of forest land for several developmental activities. Though the ill effects of forest destruction received attention during the latter half of the century, a compromise was reached between the ecologists and the advocates of wood based industries which paved the way for the concept of plantation forestry to meet fuel and pulp requirements. When this was linked with the requirements of the society, 'Social Forestry' came into being. Rao (1987) called Social Forestry as the greatest instrument of land transformation. Though the concept of Social Forestry is not new, it appeared in its present shape only during the last two to three decades.

In India, the origin of Social Forestry could be traced back to the Maurya period, when Ashoka, the great, initiated planting of trees along road sides and Budhist Sanghams. Centuries later, Tippu, the Sultan of Mysore, also followed this practice in South India. Many of the thousands of trees planted along the routes of his conquest still remain as his memorials. Again it was Tippu, who introduced Eucalyptus

Figure 1. Map of Kerala showing the location of the study



tereticornis to Mysore. Social forestry as a project of the Indian Government came during the 1960's with the primary object to supplementing fuel, fodder and small timber supply to the rural community. Social forestry programme was launched in Kerala by the State Forest Department in an extensive way with World Bank assistance. It is engaged in implementing the principal components of Social Forestry namely rehabilitation of degraded reserve forests, extension forestry and agro forestry (homestead forestry).

Extension forestry is taken up on community lands, lands available along road and railway lines, canal banks seashore, lake fringes and the premises of Government and Private Institutions. Nearly twenty species including some quick growing exotics have been planted in such lands particularly in strips of lands available at different localities. Choice of species play a vital role in social forestry programme. Fast growth, multiple use, suitability to the site and short rotation are the criteria for selection (Pande and Panda, 1988).

In the Trichur Soicial Forestry Division in the Trichur Revenue District, the large scale social forestry started in 1985. Already much work has been done by way of avenue planting, strips along road and railway lines, canal banks and other barren lands. Planting has also been done on the premises of various institutions. The main thrust in the strip plantation was on the three exotic fast growing species namely Casuarina equisetifolia, (hereafter also referred to Casuarina) Ecualyptus tereticornis (hereafter also referred to as Eucalyptus) and Acacia auriculiforms (hereafter also referred to as Acacia). But the feed back regarding the performance of these species in social forestry was very limited. Hence this study was taken to analyse the comparative performance of the three species regarding their relative rate of growth, suitability to the local condition and the impact on the surroundings. The study aimed at the identification of the best species among the three in terms of establishment and biomass production; and has been planned with the following broad objectives.

To study the periodic height girth increment, and crown development.

To study the effect on some chemical properties of the soil.

To study the impact on under growth.

To make general observations about the pattern of growth of trees, occurence of pests and diseases.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

The National Forest Policy Resolution (1988) has outlined the need for massive afforestation and social forestry programmes, consequent on the depleting forest cover and its impact on the ecosystem.

Research related to social forestry has been a comparatively new area in India. Consequent on the thrust in social forestry programmes and related activities, their has been widespread interest generated in various aspects of social forestry research. An attempt is made here to briefly review the recent work carried out in this field.

Pande and Panda (1988) coined the term, High Density Energy Plantation (HDEP), for a plantation with high density of trees (nearly 10,000/ha) at 90% survival rates and which was managed most scientifically. According to Raghav and Srivastava (1988) the choice of plant species played a vital role in the success of energy plantation and such social forestry practices. The ideal species should be suitable to site, fast growing with a short duration and having multiple uses. Work pertaining to the three species under investigation is reviewed hereunder.

2.1. *Casuarina equisetifolia* Forst.

Syn. *Casuarina muricata*

Fa. Casuarinaceae

2.1.1. Origin

The origin of most of the Casuarina species according to Encyclopaedia Britanica (1973) is in Austrialia. But the species *Casuarina equisetifolia* is of Indo-Malayan origin adapted well to the tropics and subtropics.

A native of Chittagong in Bangladesh, this species is found extensively in Burma and Andaman Islands. *Casuarina* sp. is especially of wide occurrence in wind swept sea sands along the coast (FAO, 1981).

2.1.2. General characters and requirements

Doran and Hall (1981) have reported the preference of *Casuarina equisetifolia* to sandy soils in hot humid climate. Evans (1981) has observed its nitrogen fixing capacity and drought resistant nature.

According to Yadav (1981) a well drained soil with adequate moisture and nutrient supply is essential for the species.

The optimum requirement for the species according to Bell and Evo (1983) is a porous well drained soil, adequate soil moisture and nutrients especially N, without prolonged water logging. The development of a good tap root system with abundant root nodules is important for good growth. It is relatively resistant to salinity, but in acid soils the growth is poor.

A study by Xu and Long (1983) in the Pearl river delta revealed that the main factors affecting the growth of the species were soil acidity, salt content and water level. The optimum pH was between 7 and 8.

Kondas and Jambulingam (1985) observed best growth on riverine alluvium or sandy loams with a minimum rainfall of 1000 mm.

Casuarina is a light demanding evergreen tree susceptible to drought in the sapling stage and insesitive to fire. It can withstand drought in later stages and can tolerate water logging to some extent. The growth of the species on laterite soils is poor the preference is for soils with high organic matter and nitrogen, phosphorus and potash in the soil is less important compared to the Nitrogen and Calcium level (Ramparkash and Hocking, 1986).

2.1.3. Growth and yield

Casuarina equisetifolia is a fast growing gregarious species forming pure crops in its natural state. But the growth rate varies with the locality factors (Brandis, 1921).

In a study in West Bengal, a height of 17 m and diameter of 35.5 cm was obtained in an eight years span by Ray (1971).

Kondas (1981) has reported a MAI of 10-12 mt/ha of wood at the rate of 4 to 8 kg/tree (at 2500 trees/ha). An average fire wood yield of 50 mt/ha was obtained in 5 years.

In Phillipines a growth rate of 2.27 m in height and 2.68 cm in dbh was obtained in 3 years by Halos (1981).

In the sandy soils of Sri Lanka, Casuarina attained a girth of 23.3 cm in 6 years and 26.4 cm in 7 years. The Current Annual Girth Increment was 2.4 cm and the Mean Annual Girth Increment was 3.8 cm at the 7th year (Vivekanandan, 1981).

Yadav (1981) has reported a growth rate of 6.9 m in height and 24 cm in diameter in the third year from Karnataka. A height of 3.4 m and a diameter of 11 cm were reached in the second year. While in the fourth year, these were 9.1 m and 36 cm respectively.

A comparison of Casuarina equisetifolia, Eucalyptus tereticornis and Acacia auriculiformis by Bell and Evo (1983), in an acidic clay loam soil showed poor yield in respect of Casuarina than the other two species.

A study by Kondas and Jambulingam (1985) in Tamil Nadu demonstrated nearly 40% increase in biomass by planting

2 trees per spot compared to one tree per spot. According to Ramparkash and Hocking (1986) under favourable condition the tree attains a height of 40 m and a diameter of 60 cm.

Rai and Natarajan (1988), obtained better height growth under field condition at a spacing of 1 x 1 m. In 24 months, the height was 3.48 m and the basal diameter was 3.74 cm.

2.1.4. Impact on soil

According to Lundgren (1978), afforesting a barren site with any tree species would help conserving the soil and improve nutrient status, especially if the species involved is a symbiotic N fixing one or when it has mycorrhizal association.

Thiagalingam (1981) observed that better nodulation of bacteria in Casuarina took place at the neutral pH. The species could fix upto 60 kg N/ha/year. It was observed in a young casuarina plantation that the soil nitrogen content was 0.31% and the organic carbon content was 2.52% while in an old plantation the values were as high as 0.56% and 6.14% respectively.

Casuarina soils are low in phosphorus and potash. Due to the building up of nitrogen in casuarina soils, the species is considered to be a soil improver (Ramparkash and Hocking, 1986).

2.1.5. Impact on the undergrowth

Bhaskar and Dasappa (1984) have reported that *Casuarina equisetifolia* permits undergrowth.

In its natural state casuarina is gregarious forming pure crops with no undergrowth except grasses and sporadic shrubs. The dense foliage permits very little undergrowth (Ramparkash and Hocking, 1986).

2.1.6. Survivability

According to Kondas (1981) casuarina is a browsing and fire resistant species, spared even by goats. It is also drought resistant and together with its nitrogen fixing characters contribute to the high survivability of the species.

Contrarary to earlier reports Yadav (1981) has observed large scale mortality in plantations of Karnataka in groups or individually.

Ramparkash and Hocking (1986) have observed that the high mortality rates are mostly due to drought, browsing, pest and disease attacks in the early stages.

2.1.7. Pests and diseases

Ants, bark eating cater pillars (*Arbela tetraonis*) and a longicorn beetle (*Celosterna scabrator*) are the major pests. The fungi *Trichophorous versicolor* and *Fomes* spp attack roots and cause severe damages (Ramparkash and Hocking, 1986).

2.1.8. Uses in social forestry

Kaitpraneet (1978) has suggested casuarina for planting in polluted areas while Rai and Shettigar (1979) found this species ideal for planting in areas unprotected from grazing. According to Haque (1982) the species is ideal for coastal fuel wood plantations in India.

Ramparkash and Hocking (1986) has found Casuarina as the most suitable for afforesting sandy beaches and for stabilizing sand dunes along sea coast. It also served as useful rotation crop for improving poor soils of low fertility owing to its capacity to build up soil nitrogen and organic matter levels.

2.2. *Eucalyptus tereticornis* Sm.

Syn. *Eucalyptus hybrid*

Eucalyptus umbellata

Fa. Myrtaceae

The species is called the hybrid gum or the Mysore gum in India. Some considers *E. hybrid* as a different species evolved from *E. tereticornis*.

2.2.1. Origin

"It is a native of Australia and Papua New Guinea. The open forest and wood land formation of Australia are the sealms of the eucalypts. The open wood land types are dominated by Eucalyptus and also occassionally by trees of other genera including Casuarina and Acacia" (FAO, 1981). It is an indication of the more or less common ecological requirements of the species included in the present study.

2.2.3. General characters and requirements

Banerjee (1973) has reported the unsuitability of calcareous soils for Eucalyptus tereticornis.

The species adapted to the semi humid tropics has leathery leaves and as in the case of Acacia and Casuarina has adaptations for drought resistance. It prefers a rainfall of 800-1500 mm and has been most successful in areas with summer rainfall and a moderate to fairly severe dry season. It is also fire hardy and can grow on a variety of soils, but prefers a well drained alluvium. A netural to slightly acidic pH is acceptable but not a strongly acidic one (FAO, 1981).

Thomas (1981) found that Ecualyptus shows good response to high rates of Nitrogen and Potash while application of Phosphorus had very little effect.

2.2.4. Growth and yield

On the dry laterite tract, of West Bengal Eucalyptus tereticornis recorded a mean annual volume increment of 7 to 14 m^3/ha/year (Banerjee, 1973).

Fast growing nature and its insensitivity to site quality are important attributes of the species. Height growth in early stages varied from 1-3 m/year and diameter growth from 1-2.6 cm/year. The overall average Mean Annual Increment recorded in India is 10 m^3/ha/year. Depending on site quality, the MAI varied from 2.33 to 40 m^3/ha/year (FAO, 1981).

A study conducted by Singh (1982) revealed that in a 5-9 year old plantation in the Gangetic plains the current annual net production (CANP) was more than the Mean Annual Net Production in the above ground and underground parts. The underground CANP was significantly correlated with the above ground CANP while the above ground MANP and CANP were found to be correlated with the photosynthetic biomass and total biomass respectively

In a 3 1/2 years old plantation from Karnatka, Rajan (1983) has reported a girth of 30 cm and a height of 10.5 m.

Chand Basha (1984) has reported a yield varying from 15-80 mt/ha from Eucalyptus tereticornis plantation in Kerala, while in Tamil Nadu, Shanmughanathan (1984) has reported a yield of 11 mt/ha.

In a trial for the reclammation and revegetation of coal mine over burdens in Madhya Pradesh, Eucalyptus produced height growth of 5.46 m in 2 years while Acacia auriculiformis had only 4.57 m growth (Ramprasad and Shukla, 1985).

In a comparison of Eucalyptus tereticornis with Acacia auriculiformis by Pande et al. (1987) in Bihar, Eucalyptus proved to be superior to Acacia. At the third year it had a dbh of 4.3 cm and height of 5.3 m while Acacia had a dbh of 3.4 cm and height of 3.7 m only. But in the matter of biomass production, Acacia produced 16.4 mt from 1355 trees/ha while Ecucalyptus yielded only 11.9 mt from 1120 trees/ha in Kolar in Karnataka. The average above ground biomass for Eucalyptus was 19 to 22 mt/ha in Madhalli in Karnataka.

2.2.5. Survivability

The pink disease (c.o. Corticium salmonicolor) has caused large scale mortality in the plantations in Kerala (FAO, 1981). However, Rajan (1983) has reported a survival of 94% in 3 1/2 years in Karnataka. Dayal (1984) has reported a survival of 64% from Maharashtra at the 5th year.

2.2.6. Impact on the soil

Balagopalan and Jose (1984) have reported that in Arippa in Kerala the content of organic matter and nitrogen were less in the soil of Eucalyptus than in the adjacent natural forest soil. The organic carbon content was 1.58% on the top soil in the Eucalyptus plantation. Available Nitrogen content was 1955 ppm. Both these factors decreased with depth. The soil in Eucalyptus had a pH of 5.5 and it increased with the depth.

Kushalappa (1984) found the pH to be stable around 6.7 during the 5 years of study in a Eucalyptus hybrid monoculture plantation. But the organic carbon content increased in the five years from 0.36% to 0.62%. The available phosphorus content increased (from 5.1 kg/ha to 19.2 kg/ha) while the available Potash content registered a decrease from 245.6 kg/ha to 158.3 kg/ha. Decrease in available P content with depth was also recorded.

Basu et al. (1987) have reported a reduction in soil pH in Eucalyptus plantations probably owing to leachates from the litter.

2.2.7. Impact on undergrowth

Mathur (1978) has reported that in Dehradun forests Eucalyptus tereticornis permitted luxuriant undergrowth.

Bhaskar and Dasappa (1984) are of the opinion that the species permits undergrowth only in early stages. As the plantation ages undergrowth is suppressed.

Eucalyptus hybrid leaf extract inhibits the growth of many plants, especially in low rainfall areas. Heavy rainfall nullifies the harmful effect by washing away the leachates (Rao and Reddy, 1984). According to Ramparkash and Hocking (1986) the canopy of Eucalyptus does not cause much shade and permits intercrops like cereals, oil seeds.

2.2.8. Pests and diseases

Pink disease caused by Corticium salmonicolor is common under the high rainfall and high temperature conditions of Kerala and is a major problem causing heavy mortality (Chandbasha, 1984).

Ramparkash and Hocking (1986) have reported that the species because of its the essential oil content is generally free of pests and diseases. Termites however, is one of the major pests. The borer Celosterna scabrator is also a potential pest especially in young plantations. In addition to the pink rot, root rot caused by Ganoderma lucidum chlorosis (a physiological disorder) and gummosis are the major diseases.

2.2.9. Uses in social forestry

Hannan (1979) has recommended Eucalyptus tereticornis for the rehabiliation of open coal mines owing to its impressive growth and rate of survival. Its long flowering period makes the species ideal for bee pasturage (Wali-Ur-Rahman and Choudhry, 1985).

2.3 *Acacia auriculiformis* Cunn. Ex. Benth.

Fa. Leguminosae Sub Fa. Mimosaceae

It is called Bengal wattle in India as it was first introduced in Bengal.

2.3.1. Origin

It is a native of the Savannahs of Pappua New Guinea, Northern Australia and Queensland (Ramparkash and Hocking, 1986).

2.3.2. General characters and requirements

Acacia auriculiformis is less fire hardy and succumbs to severe drought. It is browsed by cattle in the early stages and tends to be branchy. The species is an excellent seed producer and can regenerate freely under its own shade and the shade of other species (Banerjee, 1973).

According to Ramparkash and Hocking (1986) *Acacia auriculiformis* is a small to medium sized tree, evergreen in nature. With the development of phyllodes, it has adaption for drought resistance. It is a strong light demander and the stem tends to be crooked. In Indian it is seen to be a poor coppicer. It can grow on poor sites with low rainfall (660 mm). But the best growth is in the humid climate (above 1000 mm) with a dry spell of 6 months.

2.3.3. Growth and yield

On the dry laterites of West Bengal, Banerjee (1973) has reported the average height of 6.85 m and average diameter of 6.38 cm with MAI of 5 m^3/ha in the 15th year.

Lahiri (1984) has reported a growth of 1 to 2 m in height and 4 cm in collar girth in one year on a laterite tract in West Bengal. No indigenous species produced a comparable growth in the trial.

2.3.4. Survivability

According to Banerjee (1973), the survival is low due to the susceptibility to browsing in the first year and the high mortality in summer owing to the superficial root system.

Babu *et al.* (1987) have ascribed the high survivability of Acacia to the low transpiration rates observed in the species.

2.3.5. Impact on the soil

As it is a nitrogen fixing plant in association with the bacteria *Rhizobium* spp. and *Azotobacter chroococcum*, it can enrich soil ferility (Basu *et al.*, 1987).

2.3.6. Impact on the undergrowth

In a comparative study of the undergrowth in *Acacia auriculiformis*, *Eucalyptus tereticornis* and *Casuarina equisetifolia* at Bangalore by Bhaskar and Dasappa (1984). Acacia was found to support more undergrowth than Eucalyptus but lesser than Casuarina. Among the three, the undergrowth was less due to the suppressive effect of the profusely branched surface root system. There was a general reduction in undergrowth as the plantation grew old.

2.3.7. Uses in social forestry

Rai and Shettigar (1979) have recommended Acacia as ideal for planting in areas unprotected from grazing. According to the FAO (1981) the species can be planted as a green fire break due to its evergreen nature.

Catinot (1984) has suggested it as a species particularly suitable for planting as a forest fallow between agricultural crops as it can combine high productivity with ability to restore fertility.

Bell (1985) has suggested Acacia for planting on sites where cultivation is not practicable, since it requires little establishment and maintenance.

Meshram et al. (1985) have observed lac insects attacking the road side plantations in Madhya Pradesh and have suggested it as a suitable host plant for lac culture.

Because of the dense evergreen foliage it is a useful shade tree and cover crop and is useful for checking soil erosion and reclaiming waste lands (Ramparkash and Hocking, 1986).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

3.1. Selection of the plantation

A survey of the social forestry strip plantation in Trichur Social Forestry Division was carried out for selection of the experiment site. The plantation in the premises of the Sitaram Textile Mills Ltd., Trichur was selected for the experiment. The study area, prior to afforestation was barren and was used for dumping coal cinders and other wastes from the textile factory. The area was a flat laterite terrain.

The three species namely Casuarina equisetifolia, Eucalyptus tereticornis and Acacia auriculiformis were planted in rectangular strips of 0.4 ha at an espacement of 1 x 1m in May 1985 using 4 months old poly bag seedlings. This strip plantation being well inside the Trichur Municipal Town, the anthropogenic and cattle interferences were there, but, kept to the minimum during the period of study.

3.2. Lay out of the sample plots

The sample plots were laid out in Randomised Block Design (RBD) with 5 replications. The treatment were T_1 - Casuarina equisetifolia, T_2 - Acacia auriculiformis and T_3 - Eucalyptus tereticornis. Five square plots of 5 x 5 m were laid out at random for each treatment and the tree population in the plots varied from 17 to 25. Each plot was ensured a surround with at least three rows of trees on all the four sides of the plots. The boundaries of the plots were demarcated at the four corners and the casualities in each were counted and the trees numbered. The breast height of each tree was marked with a cross mark of plant, observing the standard rules. For trees, forked below the breast height, each branch was taken as a seperate tree.

3.3. Measurement of growth parameters

The growth parameters studied were, the girth at breast height (GBH), the height of the tree, the height of the lowest green branch, number of primary branches and the crown spread. GBH was measured for each tree at monthly intervals for six months from 1987 October to 1988 March. Height of the trees was measured to the nearest decimetre with the help of a graduated pole at monthly intervals. The height of the lowest green branch from the ground too was measured to the nearest decimetre. Crown width/spread was measured as the widest diametre of the crown in metres correct to the nearest centimetre. The number of primary branches were also recorded every month.

3.4. Biomass determination

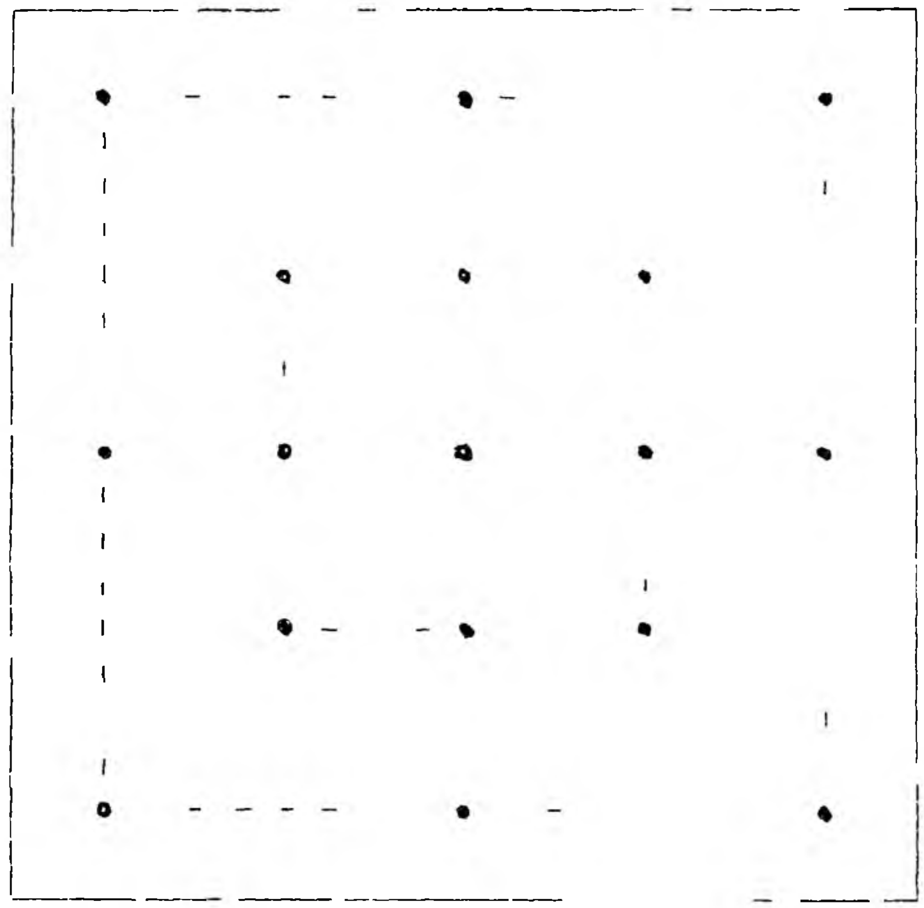
Mean tree method (Madgwick, 1971, Kaul and Gurumurthy, 1986) was adopted for the determination of biomass. In this study, GBH of the trees were measured. Later, to reduce the numerical range the readings were converted to DBH in the analysis. All the trees in each plot were grouped into 0-3 cm, 3.1-6 cm and 6.1-9 cm diameter classes. The mean DBH was calculated class wise for each species in each plot. The corresponding mean height for each mean diameter was read off graphically from the diameter height curve. Thus mean tree for each diameter class in each species was worked out. Such mean trees were selected from the surround and biomass determined by destructive sampling of two mean trees for each diameter class for all the three species.

Leaves, branches, roots and stem of the felled trees were seperated and the fresh weight of each item determined in the field. Two hundred gram representative samples of leaves and branches were oven dried at 80°C to constant weight and the dry weight determined. The main bole was divided into one metre logs and fresh weight taken. From the lower portion of each log a 5 cm thick disc was sawn off and fresh weight recorded. For the measurement of root biomass, roots in one cubic metre soil around the base of the felled tree were dug out and the loose soil sticking to them removed in running water. The roots were then air dried for two hours to remove surface moisture and then the fresh weight taken proportionately from different root zones and oven dried to obtain the dry weight of the whole root system. The number of trees per diameter class per hectare was worked out for each species on the basis of the frequency distribution of the girth classes in the plots. The average of the total biomass obtained from the two sample trees felled in each class was taken as the total biomass of the mean tree. From this the total biomass per hectare for each diameter class and the biomass per hectare or the stand were worked out.

3.5. Study of soil parameters

Composite soil samples were collected from each plot from three depths viz. 0-15 cm, 30-45 cm and 60-70 cm. The air dried 2 mm sieved samples were used for analysis. The pH was measured in a 1:2.5 soil water suspension using a Elico pH meter. The organic carbon content was estimated by Walkely and Black's titration method. Available nitrogen was calculated using C/N ratio. The available phosphorus was extracted with Bray II extractant and was determined by the molybdinum blue method. Available potassium was determined in the ammonium acetate extract using a Eel flame photo meter (Jackson, 1960). Composite samples were also collected and analysed from adjoining identical barren laterite area and those containing coal cinders.

Figure 2. Sketch of a plot showing the loci of measurement of light intensity on the floor



• Locus of measurement

3.6. Study of impact on under growth

The impact of the treatments on the under growth was studied under two heads viz. shading effect on the ground and undergrowth biomass.

Shading on the ground

The light intensity at 17 spots in each sample plot were measured at the ground level (Fig. 2) using lux meter at 8.20 a.m, 10.20 a.m, 12.20 a.m, 2.20 p.m and 4.20 p.m and their averages taken. These were compared with the light intensities at the same intervals in the adjacent open. The values were averaged and percentage light intensity in the sample plots were calculated. The measurements wer- taken monthly, on bright sunny days.

Under growth biomass

The above ground vegetation of under growth was harvested from one square meter area in the centre of each sample plot. The material was divided into grassy, herbaceous and hard wood components and the green weight taken in the field. They were then oven dried and dry weight calculated. The root biomass of the undergrowth was excluded as that would get mixed up with the roots of the main crop.

3.7. General observations

General observations were made on some aspects taking each species of a single unit. They included characters like straightness, clean bole habit, crookedness, fluting, branching habits, pest and disease incidence and wildlife habitat improvement.

RESULTS AND DISCUSSION

4. RESULTS AND DISCUSSION

A comparative study on the performance of the three tree species <u>Casuarina equisetifolia</u>, <u>Acacia auriculiformis</u> and <u>Eucalyptus tereticornis</u> gave the following results.

4.1. Diameter of the trees

The results presented in the Table 2 show the DBH valuess and increment of the three species comparing the total diameter increment and the mean annual diameter increment during the first three years. Acacia was found to be superior to Eucalyptus and Casuarina. With regard to increment during the six months of study, Acacia and Eucalyptus showed no difference from each other and they performed better than Casuarina.

In a different study by Banerjee (1978) on the dry laterites of West Bengal both Eucalyptus and Casuarina have been proved to have better growth rates than that of the present study. However the growth rate of Acacia was higher in this study. Ramprasad and Shukla (1985) have reported that, in similar trials conducted in Madhya Pradesh, Eucalyptus excelled Acacia. Reports have also indicated good growth of Acacia on acidic, neutral and alkaline soils (Hu <u>et al.</u>, 1983) probably because of nitrogen fixing ability. Relatively

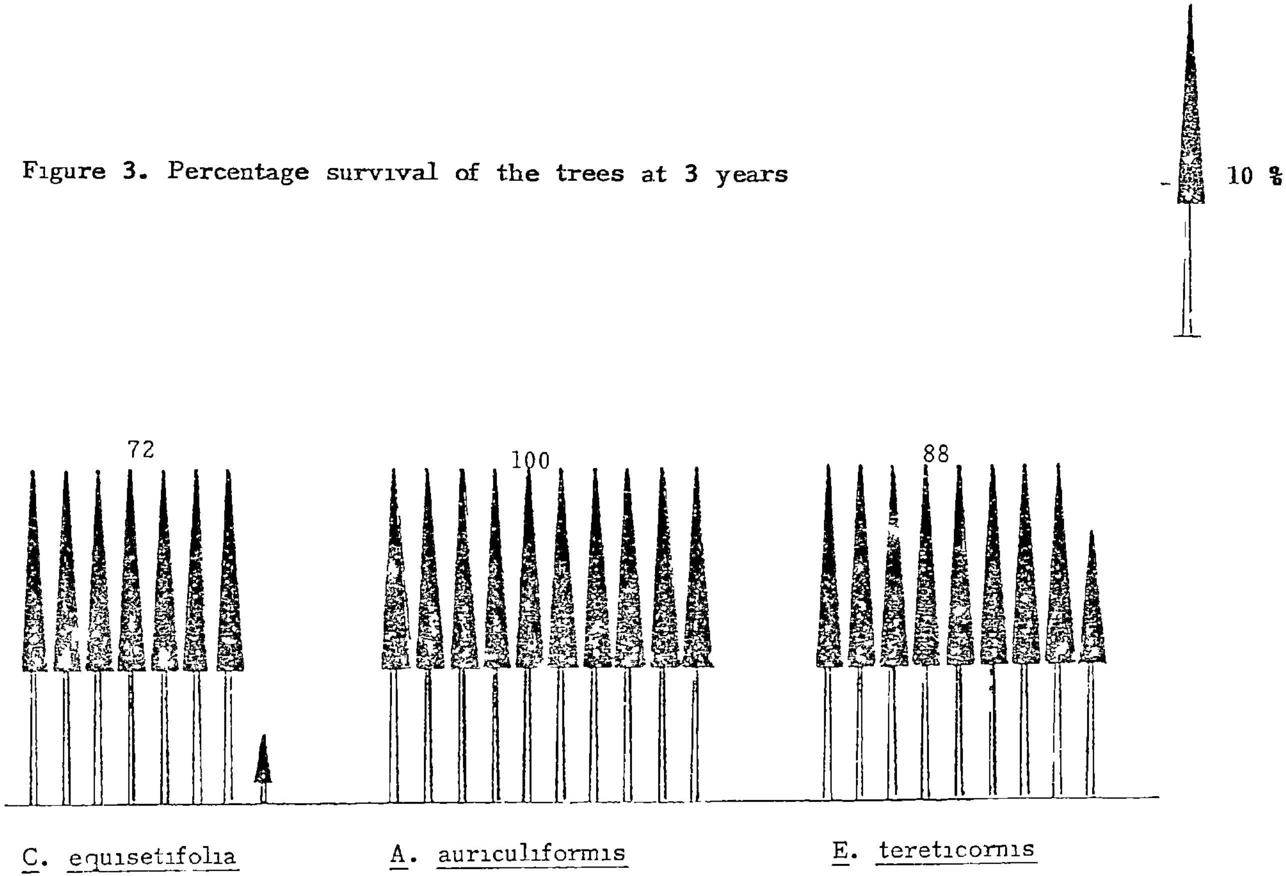
Table 1. No. of trees/plot, plant density and percentage survival in *Casuarina equisetifolia*, *Acacia auriculiformis* and *Eucalyptus tereticornis* at the third year

Species	Mean No, of* trees per plot (25 m^2)	Plant density No. of trees/ha	Percentage survival**
C. equisetifolia	18	7200	72^{a}
A. auriculiformis	25	10000	100^{c}
E. tereticornis	22	8800	88^{b}

* No. of trees/plot at the time of planting - 25

** Figures superscribed by different letters are significantly different at p = 0.05

Figure 3. Percentage survival of the trees at 3 years



higher rainfall of the site could be a reason for its better growth than that reported from West Bengal. The poor performance of Casuarina equisetifolia in this study could be due to the high browsing and the nature of the soil. Casuarina as a rule grows best in porous well drained soils rich in calcium with an optimum pH between 7 and 8. Eucalyptus was next to Acacia probably because of the humid climate which did not favour Eucalyptus. The high humidity also caused the disease Pink rot (c.o. Corticium salmonicolor) in Eucalyptus.

4.2. Height of the trees

Acacia auriculiformis was superior in total height and the mean annual height increment at the third year (Table 3). The current half years increment of the three species during the period of study did not differ significantly. Rai and Natarajan (1988) have reported a growth of 3.48 m in a 24 months while Yadav (1981) has reported 6 to 9 m in 36 months for Casuarina equisetifolia. The relatively poor growth of Casuarina and mentioned earlier in this study could be due to the heavy browsing and unfavourable soil factors. The growth rate of Eucalyptus tereticornis is on par with those reported from elsewhere. Acacia has produced better

Table 2. Diameter measurements of *Casuarina equisetifolia*, *Acacia auriculiformis* and *Eucalyptus tereticornis* at the third year

Species	DBH at 3 years (cm)	MADI at 3 years (cm)	Mean diameter increment from October 87 to March 88
C. equisetifolia	1.62 [a]	0.51 [a]	0.08 [a]
A. auriculiformis	4.56 [c]	1 44 [e]	0.34 [b]
E. tereticornis	3.82 [b]	1.20 [b]	0.29 [b]

* Figures superscribed by different letters are significantly different at $p = 0.05$

growth in height than that observed in West Bengal by Banerjee (1978) probably owing to the higher rainfall in Kerala. In a similar trial in Fiji by Bell and Evo (1983) Eucalyptus tereticornis performed he best, followed by Acacia auriculiformis and then by Casuarina equisetifolia. As in the matter of diameter growth, the same reasons could have influenced the lesser performance of Eucalyptus and inferior performance of Casuarina in this study.

4.3. Biomass of the trees

Table 4 shows the biomass produced by the three species. Here too the ranking from the top is Acacia, Eucalyptus and Casuarina. Acacia produced a yield of 98.438 mt/ha which was much higher than earlier reports by Pande et al. (1987). In addition to the other factors discussed earlier the closer spacing and the full stocking also have contributed to it. Biomass production of Eucalyptus was within the range reported in similar conditions in Kerala.

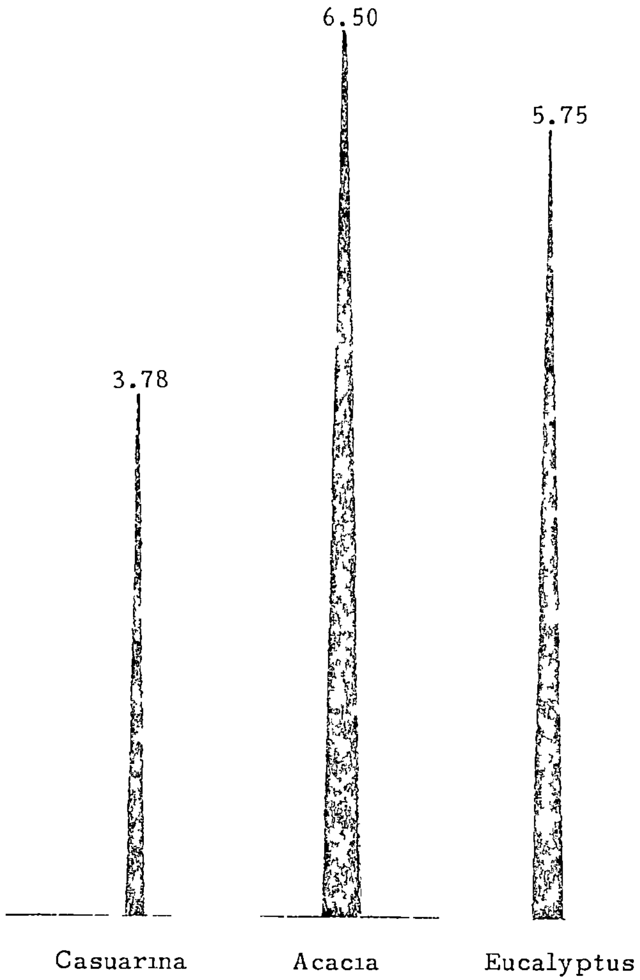
The biomass production in respect of Casuarina equisetifolia has been poor and contrarary to earlier reports Karnataka. The yield of 12.5 mt received in the present study in spite of the closer spacing as compared to the previous reports can mainly be attributed to the browsing,

Table 3. Height measurements of *Casuarina equisetifolia*, *Acacia auriculiformis* and *Eucalyptus tereticornis* at the third year

Species	Height of the trees at 3 years (m)	MAHI at 3 years (m)	Mean increment in height from October 1987 to March 1988 (m)
Casuarina equisetifolia	3.78 [a]	1.19 [a]	0.17 [a]
Acacia auriculiformis	6.50 [c]	2.05 [c]	0.27 [d]
Eucalyptus tereticornis	5.75 [b]	1.81 [b]	0.23 [a]

* Figures superscribed by different letters are significantly different at $p = 0.05$

Figure 4. Height of the trees at 3 years (m)



high mortality and unfavourable soil conditions. In the case of Casuarina, George (1977) has reported a yield of 19 mt/ha in 5 years from Meerut and Kondas (1986) has reportedd 17.75 mt/ha at 2 x 2 m spacing in 10 years from Karnataka. Considering there results and the close spacing adopted (1 x 1 m spacing gives more biomass/ha - Rai and Natarajan, 1988) it may be right to assume that the biomass production would have been higher in Casuarina had it been not for the heavy browsing, high mortality and the unfavourable soil.

4.4. Survival of the trees

Fig. 3 gives the percentage survival of the three species in the third year. Acacia registered 100% survival followed by Eucalyptus (88%) and Casuarina (72%). All the three species have been reported to be relatively drought resistant and having high survivability (Bell and Evo, 1983, Evans, 1981). Casuarina and Acacia have been particularly recommended as best suited for sites unprotected from grazing (Rai and Shettigar, 1979). These observations did prove right for Acacia auriculiformis in this study. But Casuarina faced high mortality from growing. The results obtained for Eucalyptus came well within the range of survivability reported by Narendra Prasad (1984) from Karnataka. The

Table 4. Biomass measurements of *Casuarina equisetifolia*, *Acacia auriculiformis* *Eucalyptus tereticornis* at 3 years

Species	Biomass at 3 years (mt/ha)	Mean Annual Biomass Increment at 3 years (mt/ha)	Biomass increment from October 1987 to March 1988 (mt/ha)
Casuarina equisetifolia	12.506 [a]	3.946 [a]	1.094 [a]
Acacia auriculiformis	98.438 [c]	31.053 [c]	17.867 [c]
Eucalyptus tereticornis	48.424 [b]	15.276 [b]	8.990 [b]

* Figures superscribed by different letters are significantly different at $p = 0.05$

Figure 5. Biomass of the trees at 3 years (mt/ha)

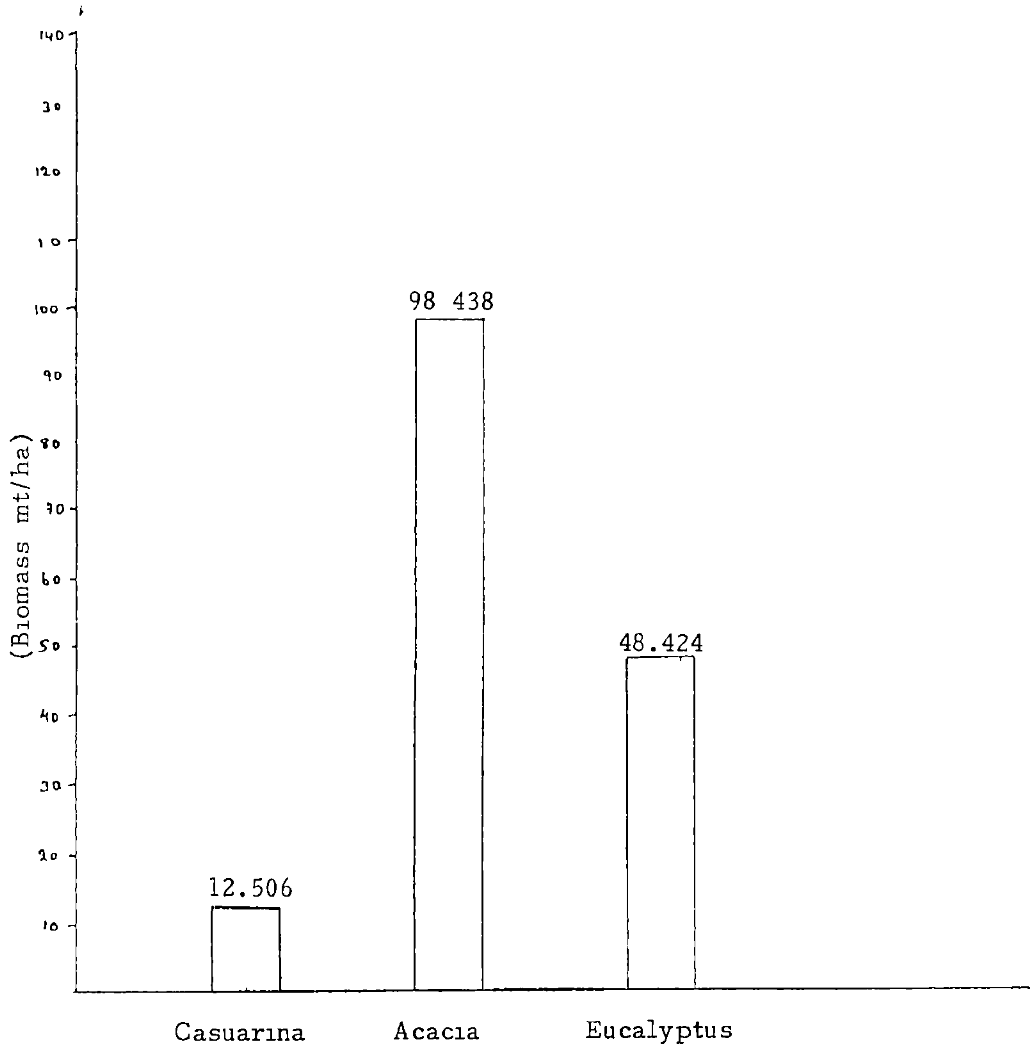
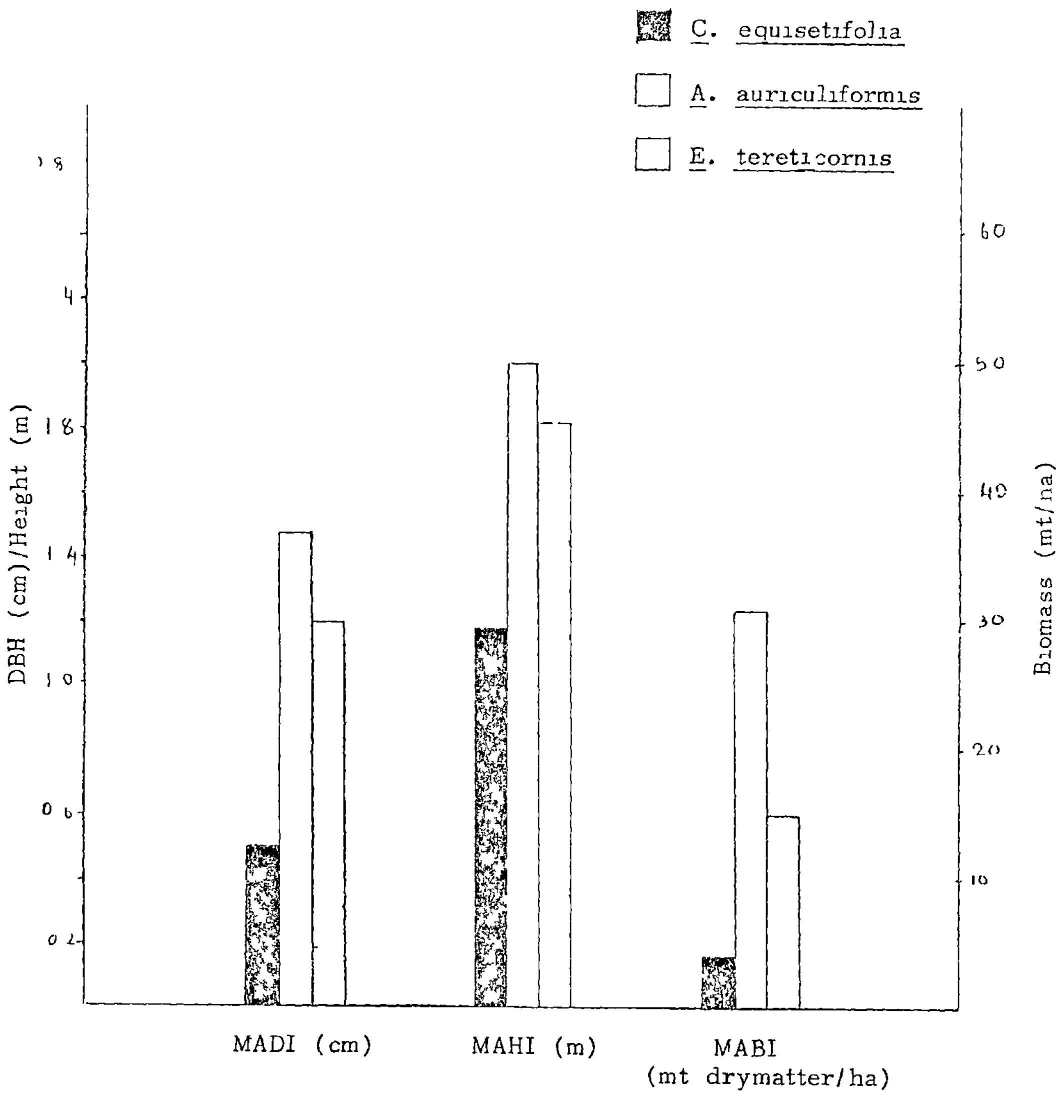


Figure 6. Mean annual diameter, height and biomass increment of the trees in 3 years



causes for the mortality in Eucalyptus could not be ascertained. But the pink disease could be one of the major suspects.

4.5. Primary branches

Table 5 shows the number of primary branches per tree. Among the three species, Eucalyptus with an average of 23.6 primary branches per tree was the best, followed by Acacia with 19.1 and Casuarina with 7.3. Considering the fact that the trees were only 3 years old, it is to be noted that only in Acacia, did the branches form a permanent part of the tree. In the other two species, branches progressively dried off from the bottom as new branches appeared. It was also observed that the progressive summer from October to March reduced the number of primary branches in Eucalyptus.

The average height of first primary branches from the ground is shown in Table 5. It was 3.18 m, in Eucalyptus, 2.22 m in Acacia and 2.16 m in Casuarina. Taking into account the greater height of the tree, it could be seen that Acacia was characterised with low primary branches resulting in a relatively poorer stem form.

Table 5. The number of primary branches, height of the first branch from the ground and crown spread at 3 years

Species	Mean No, of primary branches	Mean height of the first branch from the ground (m)	Mean crown spread (cm)
Casuarina equisetifolia	7.26 [a]	2.16 [a]	92.6 [a]
Acacia auriculiformis	19.08 [b]	2.22 [a]	98.3 [a]
Eucalyptus tereticornis	23.62 [c]	3.18 [b]	97.1 [a]

* Figures superscribed by different letters are significantly different at $p = 0.05$

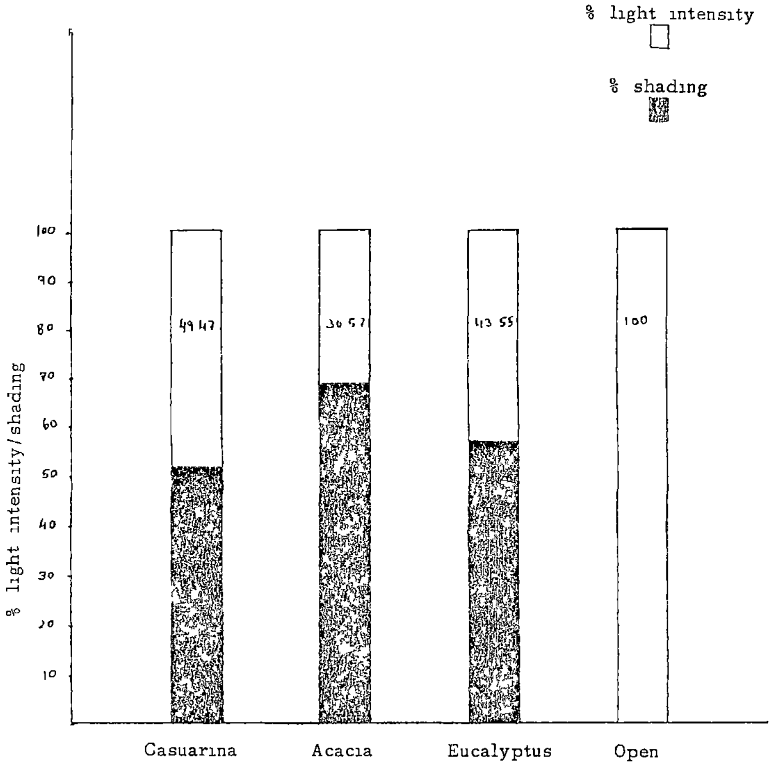
Table 6. Percentage* light intensity on the floor under *Casuarina equisetifolia*, *Acacia auriculiformis* and *Eucalyptus tereticornis* during the study period

Species	1987 October	1987 November	1987 December	1988 January	1988 February	1988 March	Mean for six months
Casuarina equisetifolia	48.89	48.90	48.91	49.16	49.2	49.47	49.09 [c]
Acacia auriculiformis	29.92	29.95	30.18	30.19	30.35	30.57	30.18 [a]
Eucalyptus tereticornis	42.72	42.71	43.37	42.79	43.42	43.35	43.09 [b]

* Percentage light intensity in the open was taken to be 100

** Figures superscribed by different letters are significantly different at $p = 0.05$

Figure 7. Percentage light intensity and shading on the floor of the plantations at 3 years



4.6. Crown spread

Table 5 shows the average crown spread of the three species. They did not differ significantly. As they were planted as monoculture in close spacing there values did not give an idea about the nature of crown spread of the species.

4.7. Impact of the species on the undergrowth

4.7.1. Shading on the floor

Fig. 7 gives the percentage light intensity on the floor under the three species. Acacia, by permitting only 30.6% of the incident light to the floor had the maximum shading effect. The least shading species was Casuarina which permitted 49.5% of the incident light to the floor. Eucalyptus was intermediate permitted 43.6% light. These values are indicative of the canopy and plant density of the three species. Acacia with a highly branched crown and the highest plant density had a closed canopy. Casuarina with a feathery crown and the lowest plant density had the lowest canopy density permitting more light.

4.7.2. Undergrowth

Fig. 9 gives the phytomass in dry weight per square meter of the undergrowth beneath the three species. The direct impact of the light intensity on the floor, on the under-

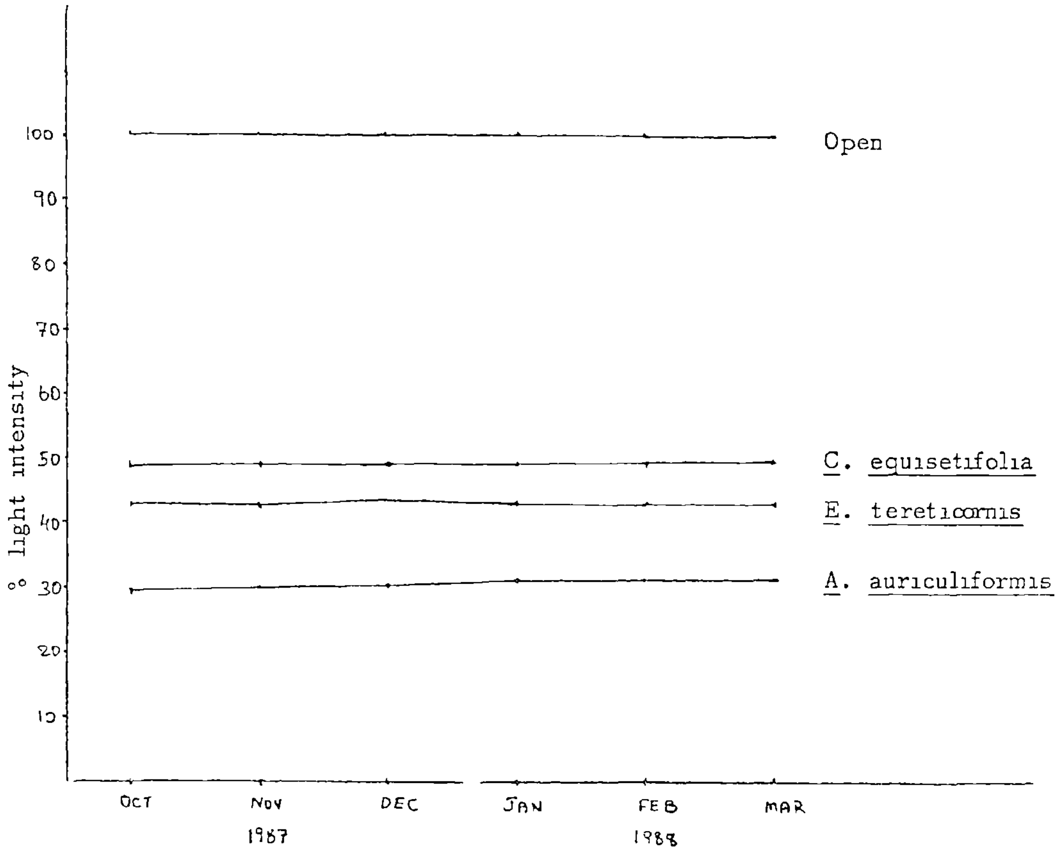


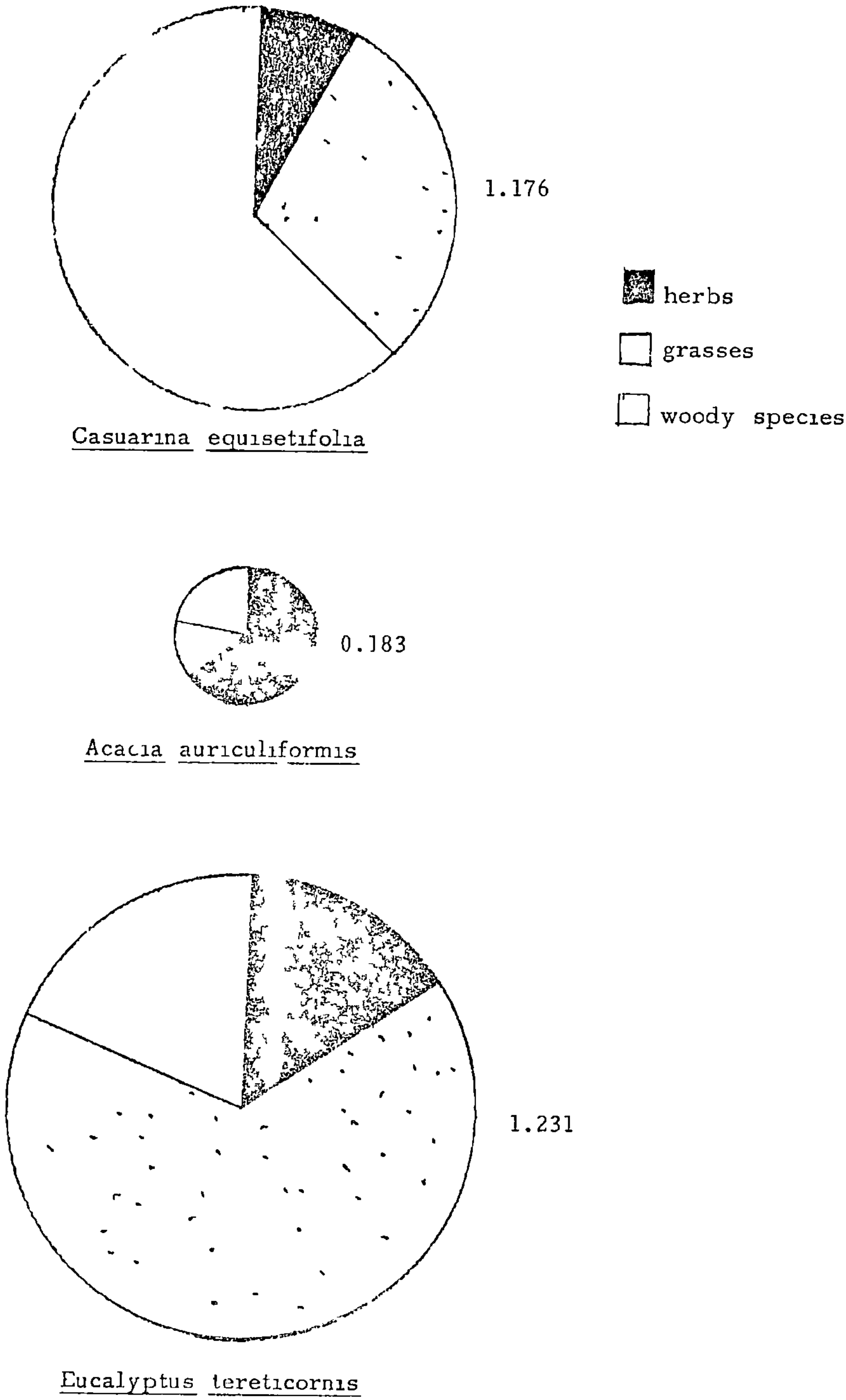
Figure 8. Percentage light intensity on the floor of the plantations from 1987 October to 1988 March

growth is very evident from the results. However in terms of phytomass in dry weight per unit area, it was Eucalyptus that had permitted the maximum undergrowth. This is in agreemennt with the findings of Mathur (1978) and Mathur and Soni (1983) in Dehradun that Eucalyptus permitted luxuriant undergrowth. The present study contradicted the general belief that the species suppressed undergrowth. Rao and Reddy (1984) have reported that the inhibitory leachates from the leaf litter could suppress undergrowth in the low rainfall area. But in high rainfall areas effects of the extracts were nullified by the heavy leaching. The present study having been conducted in a high rainfall zone, such inhibitory effects could have been removed. The undergrowth in Eucalyptus was dominated by herbs, shrubs and tree species, thereby indicating a mesophilic regime (trees and shrub) 65.5%, herbs 19.2%, grasses 15.2%. Similar findings were made by Ghosh et al. (1983). Rajvanshi et al. (1987) have reported that Eucalyptus inhibited grasses on the floor. This again is in conformity with the findings of the present study where grass in the undergrowth was minimum. Casuarina had a grass predominant undergrowth (grasses 68.5%, woody perenials 23.9%, herbs 7.67%), but due to the intensive grazing, the phytomass was lower than that obtained in Eucalyptus . In Acacia the greater shading as observed in

Table 7. Phytomass and percentage composition of the undergrowth in *Casuarina equisetifolia*, *Acacia auriculiformis* and *Eucalyptus tereticornis* plantations at the third year

Treatment	Phytomass (kg dry matter/ m^2)	Herbs %	Shrub and tree species	Grasses %
Under growth in *C. equisetifolia*	1.176 ^{b}	7.6	23.9	68.5
Under growth in *A. auriculiformis*	0.183 ^{a}	55.1	32.1	12.8
Under growth in *E. tereticornis*	1.231 ^{c}	15 2	65.6	19.2

* Figures superscribed by different letters are significantly different at $p = 0.05$


1.176
herbs
grasses
woody species
Casuarina equisetifolia
0.183
Acacia auriculiformis
1.231
Eucalyptus tereticornis

the present study naturally did not favour undergrowth except for some shade loving species. Whether the leaf litter had any inhibitory role or not was not known. Grasses, as they preferred more light, were fewer under Acacia (Trees and shrubs 56.32%, herbs 55.1%, grasses 12.8%).

The undergrowth is an indicator of the suitability of the species for intercropping. Casuarina, it appears could be raised under agriculture along with light demanding crops like cereals, because the light demand of grasses and cereals are more or less similar. Eucalyptus also seems suitable for intercropping, but with less light demanding species. Undergrowth can also serve as an indicator of the possibility of succession to a natural forest. Eucalyptus permitted more woody species. This is indicative of the possibility of Eucalyptus plot undergoing a succession to a natural forest at a faster pace if left undisturbed. They two may also serve in silvi-pastural systems.

4.8. Impact on the soil

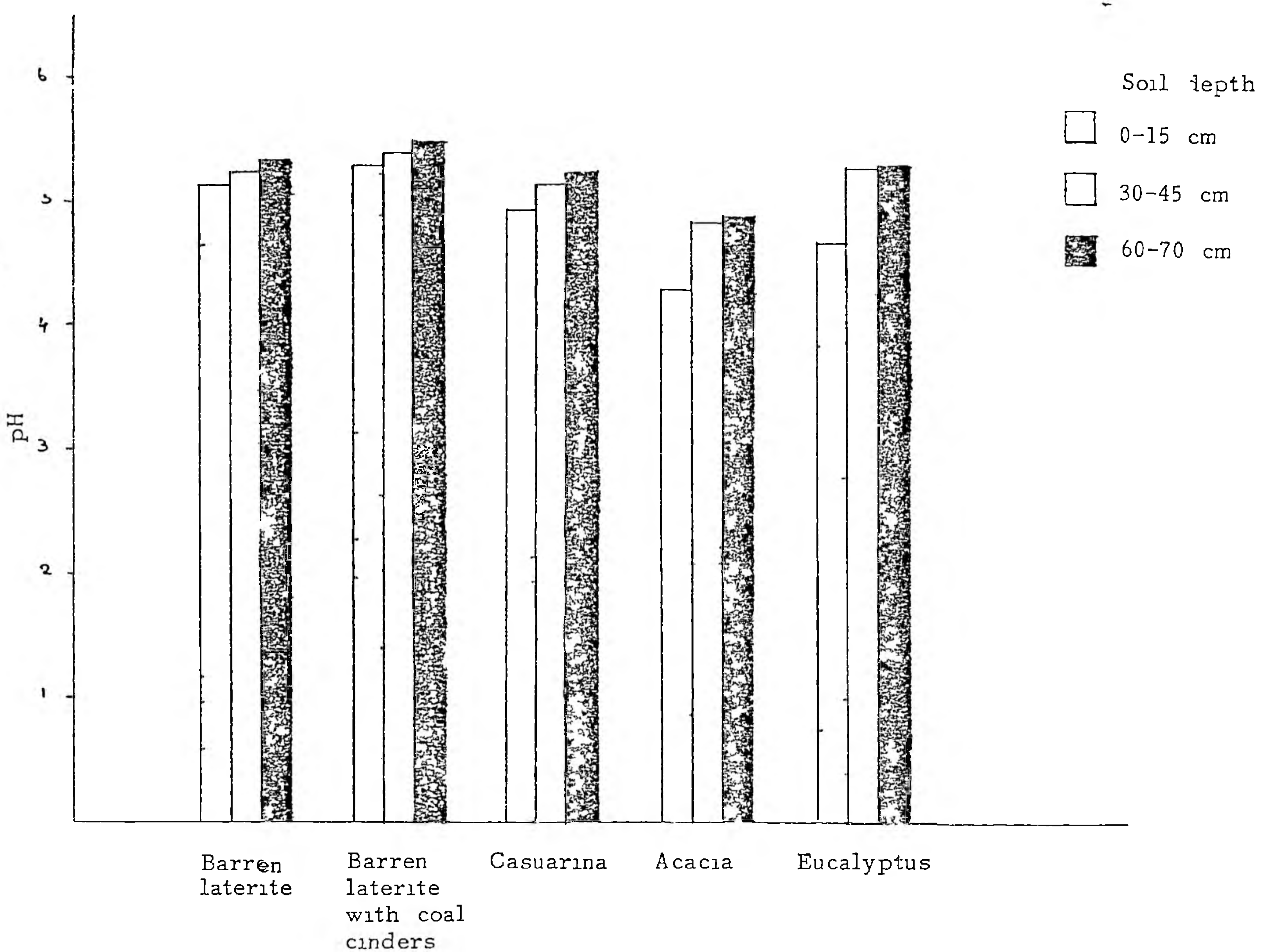
The soil of the area was laterite, with coal cinders and had higher pH, higher organic carbon content and higher available contents of nitrogen and phosphorus, compared to the barren laterite of the locality without coal cinders.

Table 8. pH of the soils under *Casuarina equisetifolia*, *Acacia auriculiformis* and *Eucalyptus tereticornis* of the third year

Treatments	Soil depth cm		
	0-15	30-45	60-70
T_0 - Barren laterite (control)	5.16 [d]	5.24 [b]	5.46 [b]
T_1 - Barren laterite with coal cinders	5.32 [e]	5.42 [c]	5.52 [c]
T_2 - Soil under *Casuarina equisetifolia*	4.94 [c]	5.17 [b]	5.24 [b]
T_3 - Soil under *Acacia auriculiformis*	4.31 [a]	4.85 [a]	4.88 [a]
T_4 - Soil under *Eucalyptus tereticornis*	4.60 [b]	5.32 [b]	5.33 [b]

* Figures superscribed by different letters are significantly different at $p = 0.05$

Figure 10. pH of the soils under the plantations at 3 years



pH of the soil

Figure 10 gives the pH of the soil at three depths in the species and two sets of uncropped soil (barren laterite and barren laterite with coal cinder). The uncropped soil containing coal cinders showed significantly higher pH than the normal laterite soil at all the three depths. Soils under all the species became more acidic compared to the normal laterite, but in varying degrees depending on the depth. At all the depth, soils under Acacia recorded the lowest pH. The pH of the top soil under all the three species was comparatively low. The lowest was for Acacia followed by Eucalyptus and Casuarina. It is noteworthy that Eucalyptus and Casuarina plantations lowered the pH of the top soil to the level of normal laterite while Acacia lowered it even further.

Organic carbon content of the soil

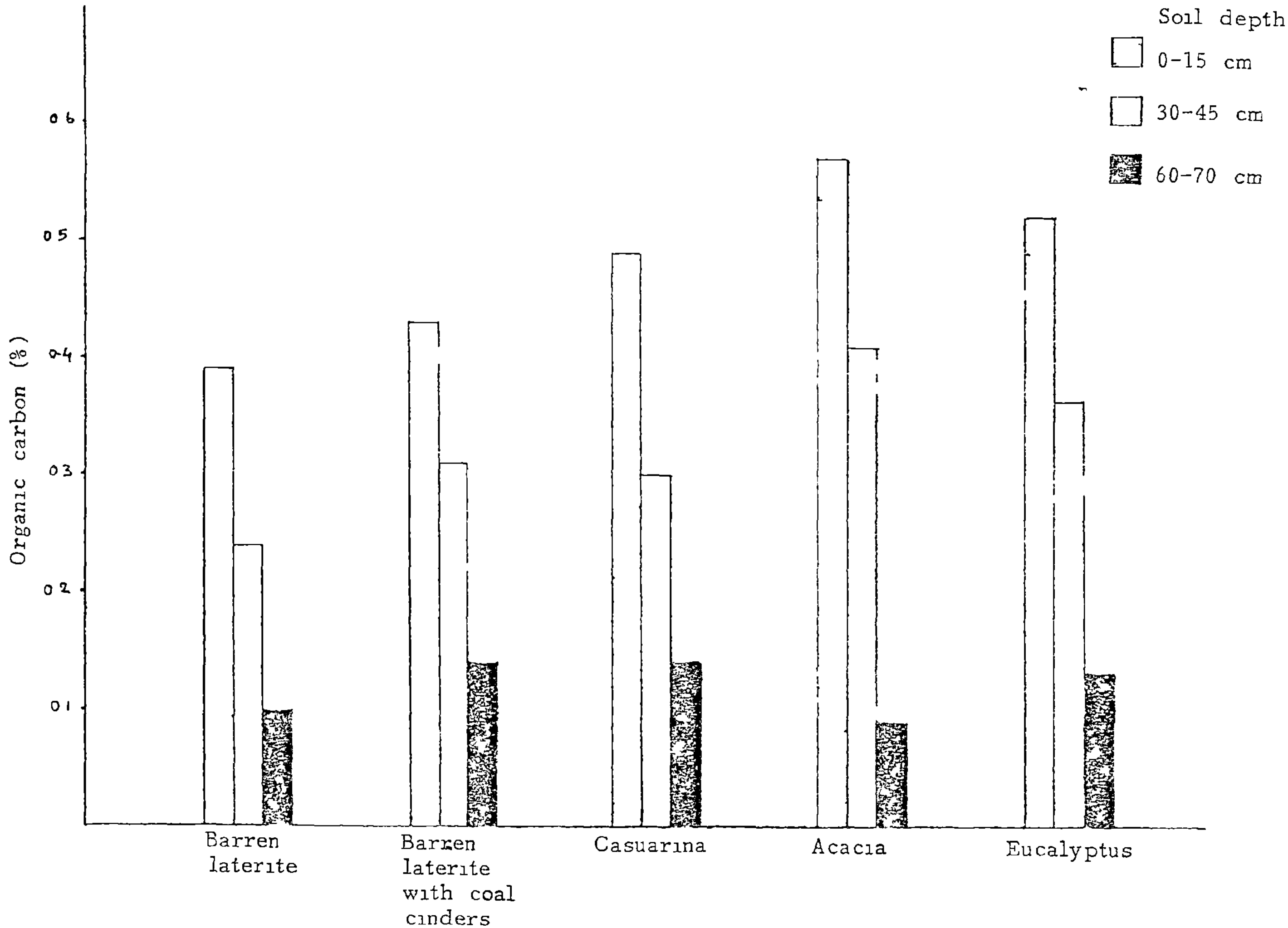
Fig. 11 gives the organic carbon content in the soils under the treatments. At 60-70 cm depth, the barren laterite soil and the soil under Acacia had the 'lowest' organic carbon content. The top soil as well as the middle layer of all the three treatments had higher content of organic carbon than the barren laterite soil and the laterite with coal cinder. Acacia soil contained the highest percentage of organic carbon followed by that of Eucalyptus and

Table 9. Percentage organic carbon content of the soil under *Casuarina equisetifolia*, *Acacia auriculiformis* and *Eucalyptus tereticornis*

Treatments	Depth of soil (cm)		
	0-15	30-45	60-70
T_0 - Barren laterite (control)	0.39 [a]	0.24 [a]	0.10 [a]
T_1 - Barren laterite with coal cinders	0.43 [b]	0.31 [b]	0.14 [b]
T_2 - Soil under *Casuaiina equisetifolia*	0.49 [c]	0.30 [b]	0.14 [b]
T_3 - Soil under *Acacia auriculiformis*	0.57 [e]	0.41 [d]	0.09 [a]
T_4 - Soil under *Eucalyptus tereticornis*	0.52 [d]	0.36 [c]	0.13 [b]

* Figures superscribed by different letters are significantly different at $p = 0.05$

Figure 11. Organic carbon content(%) of the soils under the plantations at 3 years



Casuarina. Thiagalingam (1981) has reported an organic carbon content of 2.52% in young casuarina plantation. This is contrary to the results of this study. This could be due to the removal of litter by the grazing and the low plant density. Kushalappa (1984) has reported an organic carbon content of 0.62% in 5 year old Eucalyptus plantation in Karnataka while Balagopalan and Jose (1984) have reported that the Eucalyptus top soil in Arippa forests of Kerala contained 1.58% organic carbon. All the three species have caused an increase in the organic matter content of the soil. Acacia did so better than the rest. Remembering the fact that the soil was barren before planting and that the plantation was only three years old, the performance of Eucalyptus, compares well with the finding of earlier workers.

Available nitrogen content

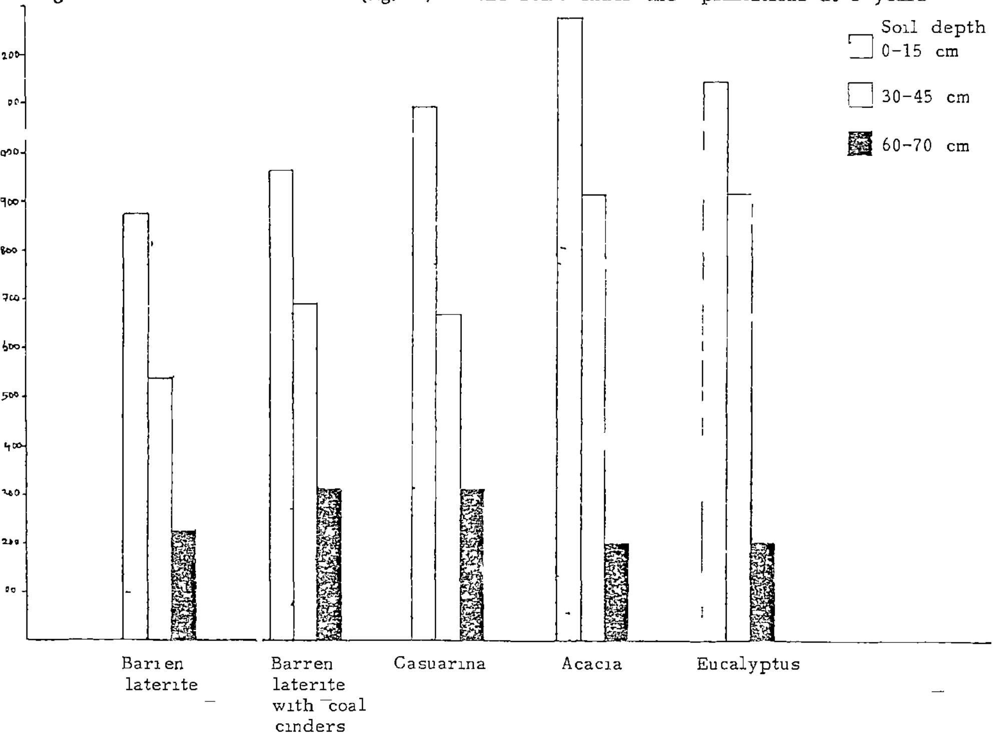
Table 10 gives the available nitrogen content of the soils. They were closely related to the organic carbon contents as revealed by the same increasing trends under the species. Acacia caused the highest rise, followed by Eucalyptus and then by Casuarina. Regarding the organic carbon content and available nitrogen content, the findings agree with that of Catinot (1984) and Basu et al. (1987) that Acacia can enrich soil fertility. Comparing with the studies

Table 10. Available Nitrogen in the soils under *Casuarina equisetifolia*, *Acacia auriculiformis* and *Eucalyptus tereticornis* (kg/ha)

Treatments	Depth of soil (cm)		
	0-15	30-45	60-70
T_0 - Barren laterite (control)	874 [a]	538 [a]	224 [a]
T_1 - Barren laterite with coal cinders	963 [b]	694 [b]	314 [b]
T_2 - Soil under *Casuarina equisetifolia*	1098 [c]	672 [b]	314 [b]
T_3 - Soil under *Acacia auriculiformis*	1277 [c]	918 [d]	202 [a]
T_4 - Soil under *Eucalyptus tereticornis*	1165 [d]	806 [c]	291 [b]

* Figures superscribed by different letters are significantly different at $p = 0.05$

Figure 12. Available N content (kg/ha) of the soils under the plantations at 3 years



by Balagopalan and Jose (1984) and Kushalappa (1984) the performance of Eucalyptus was normal, as the plantation was only 3 years old.

Available potash content

The results obtained are shown in Table 11. They did not record any significant change under the different treatments.

Available phosphorus content

The available phosphorus content of the soils are given in Table 12. In the top layer, the Acacia soil and the control without cinder had the lowest P content while the other treatments (Casuarina, Eucalyptus and the control with cinder) were above these two. At the middle layer also, the lowest was in Acacia, but this time along with both the controls. Eucalyptus and Casuarina had values higher than the rest. At the lowest layer however the available P content in the Acacia soil was very low, but it was higher than that of control soil without cinders. The other two treatments and the control with cinders had higher value.

The content of available phosphorus in the soil with coal cinders was higher than that of the soil without cinders. In Eucalyptus and Casuarina soils there was no impact of

Table 11. Available Potassium (K) in the soil under *Casuarina equisetifolia*, *Acacia auriculiformis* and *Eucalyptus tereticornis* (kg/ha)

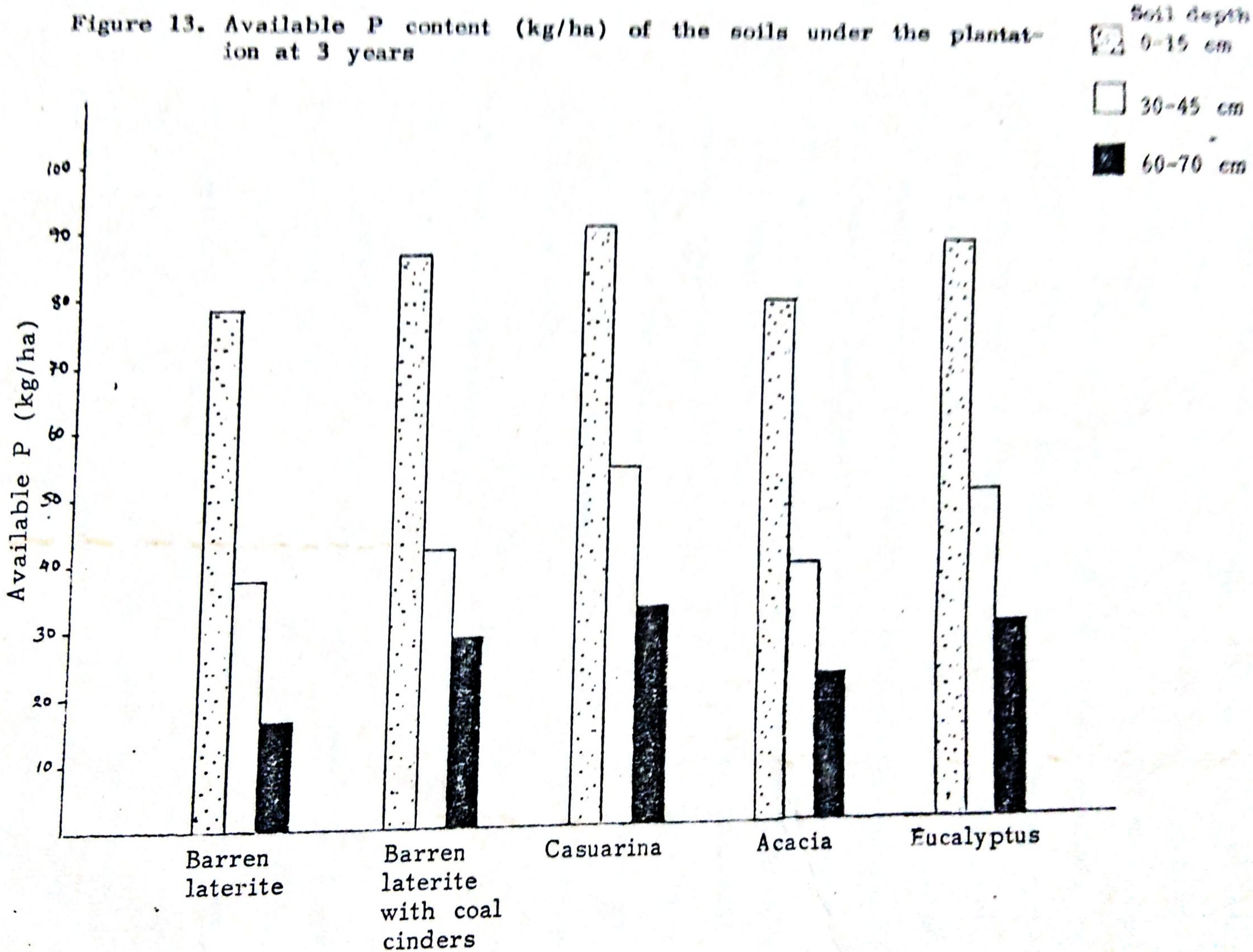
Treatments	Depth of soil (cm)		
	0-15	30-45	60-70
T_0 - Barren laterite (control)	258.4	193.2	113.2
T_1 - Barren laterite with coal cinders	322.0	221.6	153.6
T_2 - Soil under *Casuarina equisetifolia*	357.6	265.6	176.0
T_3 - Soil under *Acacia auriculiformis*	364.0	253.6	187.2
T_4 - Soil under *Eucalyptus tereticornis*	360.8	258.4	172.8

Table 12. Available Phosphorus in the soil under *Casuarina equisetifolia*, *Acacia auriculiformis* and *Eucalyptus tereticornis* (kg/ha)

Treatments	Depth of soil (cm)		
	0-15	30-45	60-70
T_0 - Barren laterite (control)	79.3 [a]	37.6 [a]	16.6 [a]
T_1 _ Barren laterite with coal cinders	87.4 [b]	42.6 [b]	29.6 [c]
T_2 - Soil under *Casuarina equisetifolia*	92.7 [b]	55.6 [d]	33.6 [c]
T_3 - Soil under *Acacia auriculiformis*	81.5 [a]	39.9 [a]	23.3 [b]
T_4 - Soil under *Eucalyptuus tereticornis*	90.0 [b]	51.1 [c]	31.4 [c]

* Figures superscribed by different letters are significantly different at $p = 0.05$

Figure 13. Available P content (kg/ha) of the soils under the plantation at 3 years



ne species on the availability of the nutrient. But Acacia has lowered the nutrient status, probably by the reducing the pH. Kushalappa (1985) had reported that Eucalyptus did increase the P availability in the soil in 5 years in Karnataka. Such an effect has not been observed here, possibly because of the age of the stand and the different soil and climatic condition. A general discussion about the impact on soil is not out of place. The results obtained in the organic carbon status and available nitrogen status confirm the opinion of Lundgren (1978) that afforesting a barren site with any tree species could be promotive to soil nutrient status. Each of the three species have been commented by various researches as soil enriching species. But there is no impact on the availability of potash. The effect on the pH of the soil is also seen undesirable, especially so in the case of Acacia.

4.9. General observations

Tree form

Casuarina and Eucalyptus were observed to grow straight with more or less clean boles, while Acacia tended to be more branchy with branched boles. No fluting was so far observed in any of the three perhaps three years is too early an age to observe anything about crookedness, fluting and branching habit. However Acacia even at this age formed permanent branches giving fewer clean boles.

Pest and diseases

No major pests and diseases were observed in Acacia and Cassuarina. But Eucalyptus was often affected by the pink disease (Corticium salmonicolor) some times leading to the breakage of the stems at the point of infection. Many casuarina trees were killed by drought and browsing.

Harbouring of wild life

Probably due to its location in the midst of the town the plantation was not found to favour wild life. Two burrows of Bandicoota indica were observed, beneath the bushy undergrowth of Eucalyptus. The population of the species was not counted. Four nests of crows were also seen. Three of these nests were atop Acacia trees while one was atop the Eucalyptus tree. Honey bees often foraged on the inflorescence of Acacia.

SUMMARY

5. SUMMARY

A study was conducted in 1987-88 on the social forestry strip plantation on the premises of the Sitaram Textile Mills Ltd. in the Trichur Social Forestry Division of Kerala State; to compare the performance of three exotic fast growing tree species, *Casuarina equisetifolia*, *Acacia auriculiformis* and *Eucalyptus tereticornis* in social forestry strip plantation. Comparisons were made on the three year old plantation in respect of growth, biomass production and impact on the soil and undergrowth. General observations were also made on the tree form, occurance of pests ar diseases and wild life habitat improvement. The site of experiment was being used for dumping coal cinders and other wastes from the textile mill and was barren before planting. The experiment was laid out in RBD with five replications. The results obtained in the study have been summarised below:

5.1. Growth parameters

At the end of the third year *Acacia auriculiformis* had a DBH of 4.56 cm followed by *Eucalyptus tereticornis* with 3.82 cm and *Casuarina equisetifolia* with 1.62 cm. The mean diameter increments were 1.44 cm/year in Acacia, 1.20 cm/year in Eucalyptus and 0.51 cm/year in Casuarina. Acacia

Acacia had more primary branches (27/tree) followed by Eucalyptus (23/tree) and Casuarina (17/tree). The first primary branch was 3.18 m above the ground in Eucalyptus 2.22 m in Acacia and 2.16 m in Casuarina. Acacia had 100% survival at the third year while Eucalyptus had 88%. But Casuarina had only 72% survival rates.

In growth as well as survival, Acacia auriculiformis was found to be the best among the three. Eucalyptus tereticornis was found superior to Casuarina equisetifolia while the later was the least impressive of the three.

5.2. Biomass production

The total biomass yield at the third year was 98.438 mt (dry matter)/ha in Acacia auriculiformis, 48.424 mt/ha in Eucalyptus tereticornis and 12.506 mt/ha in Casuarina equisetifolia. Acacia had a mean annual biomass increment of 32.813 mt/ha. MAI of Eucalyptus was 16.141 mt/ha while that of Casuarina was only 4.169 mt/ha. In biomass production too, Acacia auriculiformis was found superior to Eucalyptus tereticornis and Casuarina equisetifolia.

5.3. Impact of the undergrowth

Of the three species Casuarina equisetifolia with a light intensity on the floor of 49.5% was the least shading one, followed by *Eucalyptus tereticornis* with 43.6% and *Acacia auriculiformis* with 30.6%.

Eucalyptus was found to permit luxuriant undergrowth, so also Causarina. The above ground phytomass was 1.431 kg drymatter/m^2 in Eucalyptus and 1.176 kg/m^2 in Casuarina. But Acacia was found to inhibit undergrowth (0.183 kg/m^2). Even the little undergrowth that was permitted by it comprised mostly of its own seedlings. The undergrowth in Eucalyptus comprised mostly of woody species (65.6%) while that of Casuarina comprised mostly of grasses (68.5%).

5.4. Impact on the soil

The presence of coal cinders had caused a rise in the soil pH, organic matter content, available Nitrogen content and available Phosphorus content of the soil.

The lowest pH value in the top soil was found in Acacia soil 4.31. Eucalyptus soil had 4.69 and Casuarina soil had 4.94 compared to the barren laterite (5.16) and the barren laterite with coal cinders (5.32). At the depth of 30-45 cm, the pH values were 4.85 in Acacia soil, 5.17 in Casuarina soil and 5.32 in Eucalyptus soil. The barren laterite had a pH of 5.24 and in the barren laterite with coal cinders it was 5.42. The pH at 60-70 cm depth was 4.88 in Acacia soil 5.24 in Casuarina soil, 5.33 in Eucalyptus soil, 5.36 in barren laterite and 5.52 in barren laterite with coal cinders. All the three species reduced the pH of the soil. But *Acacia auriculiforms* was found to lower the pH of the soil more than the other two. pH increased with the depth in all the treatments.

The organic carbon contents in the top soils were 0.57% in Acacia, 0.41% in Eucalyptus, 0.49% in Casuarina, 0.3% in barren laterite and 0.43% in barren laterite with coal cinders. The organic matter content was found to decrease as depth increased in all the treatments. There was a general rise in the organic carbon content of the soils due to the impact of the three species with the maximum in Acacia soil and the minimum in Casuarina soils.

The available Nitrogen content in the top soil was 1277 kg/ha in Acacia, 1165 kg/ha in Eucalyptus, 1098 kg/ha in Casuarina, 874 kg/ha in barren laterite and 963 kg/ha in barren laterite with coal cinders. There was a reduction in the available Nitrogen content as the soil depth increased in all the treatments. All the three species caused an increase in the available Nitrogen content of the soil, the highest being observed in *Acacia auriculiformis* followed by *Eucalyptus tereticornis*.

The available Potash content of the soils did not record any change under the different species.

The available Phosphorus contents of the top soils were 92.7 kg/ha in Casuarina, 90 kg/ha in Eucalyptus, 81.5 kg/ha in Acacia, 79.3 kg/ha in barren laterite and 87.4 kg/ha in the barren laterite with coal cinders. There was reduction in the content of the nutrient as depth increased in all the treatments. In Acacia soils the content of the available Phosphorus had decreased.

Regarding the general observations, Acacia auriculiformis showed pronounced branching habits while Eucalyptus and Casuarina had more or less clean boles. Pests and diseases were not observed excepting the pink disease (c.o. Corticium salmonicolor) in Eucalyptus. Crows and rodents were the principal representatives of wild life in the plantation. Honey bees commonly foraged the inflorescence of Acacia.

Acacia auriculiformis proved itself to be a highly promising tree for energy plantations and for afforesting sites dumped with coal cinders and for sites offering little protection from anthropogenic influences and grazing. It also improved the organic matter content and available nitrogen content of the soil and was free from graziers. But at the same time there were also unwelcome effects due to Acacia such as increasing the acidity of the soil and suppressing undergrowth. It also tended to be highly branching.

Eucalyptus tereticornis also was found to be good in growth and biomass production and could be recommended for similar sites. The species also enriched the soil by increasing the contents of organic carbon and available Nitrogen. Though it too reduced the pH of the soil, the species was found to support luxurient undergrowth and was spared by graziers.

Casuarina equisetifolia was a less suitable species for such a site as seen from the performance of the species. It suffered heavily from browsing and showed lesser survival growth and yield. But the species increased the organic carbon content and available Nitrogen content of the soil and permitted luxurient undergrowth especially grasses.

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APPENDICES

Appendix-1
Weather data for Trichur

A. Normal rainfall (mm) in Trichur*

April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	Total
86.6	274.3	803.4	761.4	458.6	250.3	307.5	158.3	30.3	9.3	8.8	28.6	3177.4

B. Statistic of climatic variables during 1987-88 for Trichur**

Var. Stat.	1987									1988			
	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	Total/Mean
Mean air Temp. (°C)	29.7	29.5	26.8	26.1	26.8	26.6	27.5	27.6	27.5	27.8	28.8	29.9	27.88
Rainfall (mm)	13.3	95	837.7	336.7	388.4	174	280.4	224.4	64.6	-	7.8	37.9	2460.2
No. of rainy days	1	3	21	17	22	8	16	6	6	-	1	2	103
Mean Rel. Humidity (%)	64	666	83	84	87	79	79	77	70	56	56	67	72.33

* Source - Farm guide 1988. Farm Information Bureau, Kerala.
** Source - Dept. of Agro-metereology, Kerala Agrl. University, Trichur.

Appendix-2

Measurements of the mean trees in *Casuaria equisetifolia*, *Acacia auriculiformis* and *Eucalyptus tereticornis* at 2 1/2 years age

Species	Diameter class(cm)	Diameter (cm)	Height* (m)	Biomass** (gm dry wt.)			
				Root	Wood	Foliage	Total
	0-3	1.36	3.35	144.25	664.13	223.15	1031.53
C. equisetifolia	3.1-6	3.38	6.25	357.88	4083.75	2845.70	7286.83
	6.1-9	-	-	-	-	-	-
	0-3	2.26	5.25	240.16	1473.18	1046.70	2760.04
A. auriculiformis	3.1-6	4.42	6.55	475.40	3883 83	1279.30	5638.52
	6.1-9	6.75	7.40	724.93	13660.35	3721.60	18106.88
	0-3	1.70	4.05	140.91	664.13	223.15	1028.19
E. tereticornis	3.1-6	4.30	6.55	366.45	3851.93	669.45	4887.83
	6.1-9	7.10	8.10	596.51	13548.15	1785.20	15929.86

* Derived from Diameter - Height curve

** Mean values of two sample trees each

Appendix-3

Measurement of the mean trees in *Casuarina equisetifolia*, *Acacia auriculiformis* and *Eucalyptus tereticornis* at 3 years age

Species	Diameter class (cm)	Diameter (cm)	Height* (m)	Biomass** (gm dry wt.) Root	Wood	Foliage	Total
	0-3	1.35	3.25	141.37	601.98	212.33	955.67
C. equisetifolia	3.1-6	3.63	6.72	379.18	4332.30	3058.03	7769.51
	6.1-9	-	-	-	-	-	-
	0-3	2.18	5.15	234.69	1414.25	960.64	2609.57
A. auriculiformis	3.1-6	4.52	6.60	485.01	3974.89	1286.28	5746.18
	6.1-9	6.7	7.35	722.99	13563.92	3675.08	17961.99
	0-3	1.34	3.57	121.07	520.67	151.74	793.49
E. tereticornis	3.1-6	4.2	6.45	358.13	4024.60	504.32	4887.05
	6.1-9	6.95	8.00	587.07	13266.56	1700.40	15554.03

* Derived from Diameter - Heigt curve
** Mean values of two sample trees each

Appendix-4

Biomass measurement of the trees (Diameter class wise) in *Casuarina equisetifolia* (gm dry wt./plot)

Age (year)	Plot	Diameter class	Trees/ diameter class	Biomass/ Diameter class (gm dry wt.)	Total Biomass/ plot (gm dry wt.)
		0-3	16	16504	
2·5	I	3.1-6	2	14574	31078
		6.1-9	-	-	
		0-3	20	20631	
	II	3.1-6	-	-	20631
		6.1-9	-	-	
		0-3	19	19599	
	III	3.1-6	-	-	19599
		6.1-9	-	-	
		0-3	16	16505	
	IV	3.1-6	1	7287	23191
		6.1-9	-	-	
		0-3	13	13410	
	V	3.1-6	5	36434	49844
		6.1-9	-	-	
3		0-3	15	14335	
	I	3.1-6	3	23309	37644
		6.1-9	-	-	
		0-3	19	18158	
	II	3.1-6	-	-	18158
		6.1-9	-	-	
		0-3	17	17202	
	III	3.1-6	1	7770	24972
		6.1-9	-	-	
		0-3	16	15291	
	IV	3.1-6	1	7770	23060
		6.1-9	-	-	
		0-3	13	12424	
	V	3.1-6	5	38848	51272
		6.1-9	-	-	

Appendix-5

Biomass measurement of trees (Diameter class wise) in *Eucalyptus tereticornis* (gm dry wt./plot)

Age (Years)	Plot	Diameter class	Trees/ diameter class*	Biomass/ diameter class (gm dry wt.)	Total Biomass/ plot (gm dry wt.)
2.5		0-3	8	8225	
	I	3.1-6	11	53766	107781
		6.1-9	3	47780	
		0-3	6	6169	
	II	3.1-6	11	53766	139584
		6.1-9	5	79649	
		0.3	10	10282	
	III	3.1-6	12	58654	68936
		6.1-9	-	-	
		0-3	12	12338	
	IV	3.1-6	11	53766	97964
		6.1-9	2	31860	
		0-3	8	8225	
	V	3.1-6	14	68430	76655
		6.1-9	-	-	
3		0-3	6	4761	
	I	3.1-6	12	58645	110068
		6.1-9	3	46662	
		0-3	6	4761	
	II	3.1-6	8	39096	168289
		6.1-9	8	124432	
		0-3	7	5554	
	III	3.1-6	13	63532	100194
		6.1-9	2	31108	
		0-3	7	5554	
	IV	3.1-6	14	68419	126554
		6.1-9	14	62216	
		0-3	7	5554	
	V	3.1-6	13	63532	100194
		6.1-9	2	31108	

* Each Fork of the trees branching below the bh was taken as a seperate tree

Biomass measurement of the trees (Diameter class wise) in Acacia auriculiformis (gm dry wt./plot)

Age (years)	Plot	Diameter class	Trees/ diameter class	Biomass/ diameter class (gm dry wt.)	Total Biomass/ plot (gm dry wt.)
2·5	I	0-3	10	27600	
	I	3.1-6	28	157879	221693
		6.1-9	2	36214	
		0-3	4	11040	
	II	3.1-6	23	129686	158833
		6.1-9	1	18107	
		0-3	7	19320	
	III	3.1-6	24	135325	227072
		6.1-9	4	72428	
		0-3	2	5520	
	IV	3.1-6	33	186071	209698
		6.1-9	1	18107	
		0-3	5	13800	
	V	3.1-6	28	157879	189785
		6.1-9	1	18107	
3		0-3	7	18267	
	I	3.1-6	28	160893	268970
		6.1-9	5	89810	
		0-3	2	5219	
	II	3.1-6	20	114924	227915
		6.1-9	6	107772	
		0-3	7	18267	
	III	3.1-6	21	120670	264671
		6.1-9	7	125734	
		0-3	2	5219	
	IV	3.1-6	30	172385	249452
		6.1-9	4	71848	
		0-3	4	10438	
	V	3.1-6	27	155147	219471
		6.1-9	3	53886	

Appendix-7

Abstract of analysis of variance table for DBH (cm) of the trees at 3 years

Source	DF	SS	MSS	F
Block	4	.120	.030	.175
Treatment	2	23.385	11.693	68.379
Error	8	1.368	.171	
Total	14	24.873		

SE of any treatment mean = .1849
CD at 5% level = .6031
CD at 1% level = .8774

Appendix-8

Abstract of analysis of variance table for Mean Annual Diameter Increment (cm) of trees of 3 years

Source	DF	SS	MSS	F
Block	4	.013	.003	.187
Treatment	2	2.315	1.158	68.128
Error	8	.136	.017	
Total	14	2.464		

SE of any treatment mean = .0583
CD at 5% level = .1901
CD at 1% level = .2766

Appendix-9

Abstract of analysis of variance table for mean diameter increment of the trees (cm) from October '87 to March '88

Source	DF	SS	MSS	F
Block	4	.001	.000	.069
Treatment	2	.195	.097	34.704
Error	8	.022	.003	
Total	14	.218		

SE of any treatment mean = .0237
CD at 5% level = .0772
CD at 1% level = .1123

Appendix-10

Abstract of the analysis of variance table for the height (m) of the trees at 3 years

Source	DF	SS	MSS	F
Block	4	.120	.030	.139
Treatment	2	19.674	9.837	45.447
Error	8	1.732	.216	
Total	14	21.525		

SE of any streatment mean = .2081
CD at 5% level = .6785
CD at 1% level = .9872

Appendix-11

Abstract of the analysis of variance table for Mean Annual Height Increment (m) of the trees at 3 years

Source	DF	SS	MSS	F
Block	4	.012	.003	.145
Treatment	2	1.959	.980	45.466
Error	8	.172	.022	
Total	14	2.144		

SE of any treatment mean = .0656
CD at 5% level = .2141
CD at 1% level = .3115

Appendix-12

Abstract of the analysis of variance table for mean heigh increment (cm) of the trees from October '87 to March '88

Source	DF	SS	MSS	F
Block	4	64.667	16.167	.520
Treatment	2	241.733	120.867	3.884
Error	8	248.933	31.117	
Total	14	555.333		

SE of any treatment mean = 2.4947
CD at 5% level = 8.1355
CD at 1% level = 11.8364

Appendix-13

Abstract of the analysis of variance table for the biomass (kg drymatter/plot) of the trees at 3 years

Source	DF	SS	MSS	F
Block	4	467.313	116.828	.173
Treatment	2	116416.275	58208.146	86.102
Error	8	5408.281	676.035	
Total	14	122291.874		

SE of any treatment mean = 11.6279
CD at 5% level = 37.9205
CD at 1% level = 55.1705

Appendix-14

Abstract of the analysis of variance table for MABI of the trees (kg drymatter/plot) at 3 years

Source	DF	SS	MSS	F
Block	4	46.531	11.633	173
Treatment	2	11584.398	5792.199	86.102
Error	8	538.168	67.271	
Total	14	12169.097		

SE of any treatment mean = 3.6680
CD at 5% level = 111.9620
CD at 1% level = 17.4035

Appendix-15

Abstract of the analysis of variance table for mean biomass increment (kg drymatter/plot) of the trees from October '87 to March '88

Source	DF	SS	MSS	F
Block	4	414.157	103.539	.699
Treatment	2	4400.701	2200.350	14.862
Error	8	1184.444	148.055	
Total	14	5999.301		

SE of any treatment mean = 5.4416
CD at 5% level = 17.7460
CD at 1% level = 25.8187

Appendix-16

Abstract of the analysis of variance table for the survival percentage of the trees at 3 years

Source	DF	SS	MSS	F
Block	4	10.672	2.668	.400
Treatment	2	1973.336	986.668	148.015
Error	8	53.328	6.666	
Total	14	2037.336		

SE of any treatment mean = 1.1546
CD at 5% level = 3.7655
CD at 1% level = 5.4784

Appendix-17

Abstract of the analysis of variance table for the number of primary branches of the trees at 3 years

Source	DF	SS	MSS	F
Block	4	6.331	1.583	.394
Treatment	2	713.290	356.645	88.727
Error	8	32.157	4.020	
Total	14	751.777		

SE of any treatment mean = .8966
CD at 5% level = 2.9240
CD at 1% level = 4.2542

Appendix-18

Abstract of the analysis of variance table for the mean height (m) of the first branch from the ground at 3 years

Source	DF	SS	MSS	F
Block	4	.151	.038	1.087
Treatment	2	3.276	1.638	47.252
Error	8	.277	.035	
Total	14	3.704		

SE of any treatment mean = .0833
CD at 5% level = .2715
CD at 1% level = .3951

Appendix-19

Abstract of the analysis of variance table for the percentage light intensity on the floor of the plantations at 3 years

Source	DF	SS	MSS	F
Block	4	10.262	2.565	3.811
Treatment	2	933.900	466.950	693.735
Error	8	5.385	.673	
Total	14	949.547		

SE of any treatment mean = 3669
CD at 5% level = 1.1965
CD at 1% level = 1.7408

Appendix-20

Abstract of the analysis of variance table for the phytomass (kg drymatter/m^2) of the undergrowth at the 3rd year

Source	DF	SS	MSS	F
Block	4	003	.001	.805
Treatment	2	3.480	1.740	1618.190
Error	8	.009	.001	
Total	14	3.492		

SE of any treatment mean = .0147
CD at 5% level = .0478
CD at 1% level = .0696

Appendix-21

Abstract of the analysis of variance table for the pH of the soils at three years

Source	DF	SS	MSS	F
Total	74	8.312		
Block	4	.026	.007	.389
Treatment	4	4.521	1.130	67.068
Variety	2	2.085	1.042	61.860
Interac	8	.736	.092	5.460
Error	56	.944	.017	

Standard Error of means = .058
CD for comparative levels of treatments
(i) at 5% = .095 (ii) at 1% = .126

Appendix-22

Abstract of the analysis of variance table for the organic carbon content (per cent) of the soil at 3 years

Source	DF	SS	MSS	F
Total	74	1.872		
Block	4	.001	.000	.322
Treatment	4	.118	.029	35.074
Variety	2	1.630	.815	971.020
Interac	8	.076	.009	11.307
Error	56	047	.001	

Standard Error of means = .013
CD for comparative levels of treatments
(i) at 5% = .021 (ii) at 1 % = .028

Appendix-23

Abstract of the analysis of variance table for the available P content (ppm) of the soil

Source	DF	SS	MSS	F
Total	74	10120.348		
Block	4	8.613	2.153	.319
Treatment	4	517.680	129.420	19.164
Variety	2	9181.548	4590.774	679.777
Interac	8	34.320	4.290	.635
Error	56	378.187	6.753	

Standard Error of means = 1.162
CD for comparing levels of treatments
(i) at 5% = 1.901 (ii) at 1% - 2.531

COMPARATIVE PERFORMANCE OF THREE EXOTIC TREE SPECIES IN SOCIAL FORESTRY STRIP PLANTING IN TRICHUR SOCIAL FORESTRY DIVISION

BY
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ABSTRACT OF A THESIS
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ABSTRACT

A study was conducted in 1987-88 on the social forestry strip plantation on the premises of the Sitaram Textile Mills Ltd. in the Trichur Social Forestry Division of Kerala State, to compare the performance of three exotic fast growing tree species, Casuarina equisetifolia, Acacia auriculiformis and Eucalyptus tereticornis in social forestry strip plantation. Comparisons were made on the three year old plantation in respect of growth, biomass production and impact on the soil and undergrowth. General observations were also made on the tree form, occurance of pests and diseases and wild life habitat improvement. The site of experiment was being used for dumping coal cinders and other wastes from the textile mill and was barren before planting. The experiment was laid out in RBD with five replications. The results obtained in the study have been summarised below:

At the end of the third year Acacia auriculiformis had a DBH of 4.56 cm followed by Eucalyptus tereticornis with 3.82 cm and Casuarina equisetifolia with 1.62 cm. The mean annual diameter increments were 1.44 cm/year in Acacia, 1.20 cm/year in Eucalyptus and 0.51 cm/year in Casuarina. Acacia had more primary branches (27/tree) followed by Eucalyptus

(23/tree) and Casuarina (17/tree). The first primary branch was 3.18 m above the ground in Eucalyptus, 2.22 m in Acacia and in 2.16 m in Casuarina. Acacia had 100% survival at the third year while Eucalyptus had 88%. But Casuarina had only 72% survival rates.

In growth as well as survival, _Acacia auriculiformis_ was found to be the best among the three. _Eucalyptus tereticornis_ was found superior to _Casuarina equisetifolia_ while the latter was the least impressive of the three.

The total biomass yield at the third year was 98 438 mt (drymatter)/ha in _Acacia auriculiformis_, 48.424 mt/ha in _Eucalyptus tereticornis_ and 12.506 mt/ha in _Casuarina equisetifolia_. Acacia had a mean annual biomass increment of 32.813 mt/ha. MAI of Eucalyptus was 16.141 mt/ha while that of Casuarina was only 4.169 mt/ha. In biomass production too, _Acacia auriculiformis_ was found superior to _Eucalyptus tereticornis_ and _Casuarina equisetifolia_.

Of the three species _Casuarina equisetifolia_ with a light intensity on the floor of 49.5% was the least shading one, followed by _Eucalyptus tereticornis_ with 43.6% and _Acacia auriculiformis_ with 30.6%.

Eucalyptus was found to permit luxurient undergrowth, so also casuarina. The above ground phytomass was 1.431 kg drymatter/m^2 in Eucalyptus and 1.176 kg/m^2 in Casuarina. But Acacia was found to inhibit undergrowth (0.183 kg/m^2). Even the little undergrowth that was permitted by it comprised mostly of its own seedlings. The undergrowth in Eucalyptus comprised mostly of woody species (65.6%) while that of casuarina comprised mostly of grasses (68.5%).

The presence of coal cinders had caused a rise in the soil pH, organic matter content, available Nitrogen content and available phosphorus content of the soil.

The lowest pH value in the top soil was found in Acacia soil 4.31. Eucalyptus soil had 4.69 and Casuarina soil had 4.94 compared to the barren laterite (5.16) and the barren laterite with coal cinders (5.32). At the depth of 30-45 cm, the pH values were 4.85 in Acacia soil, 5.17 in Casuarina soil and 5.32 in Eucalyptus soil. The barren laterite had a pH of 5.24 and in the barren laterite with coal cinders it was 5.42. The pH at 60-70 cm depth was 4.88 in Acacia soil 5.24 in Casuarina soil, 5.33 in Eucalyptus soil, 5.36 in barren laterite and 5.52 in barren laterite with coal cinders. All the three species reduced the pH of the soil. But Acacia auriculiformis was found to lower the pH of the soil more than the other two. pH increased with the depth in all the treatments.

The organic carbon contents in the top soils were 0.57% in Acacia, 0.41% in Eucalyptus, 0.49% in Casuarina, 0.39% in barren laterite and 0.43% in barren laterite with coal cinders. The organic matter content was found to decrease as depth increased in all the treatments. There was a general rise in the organic carbon content of the soils due to the impact of the three species with the maximum in Acacia soils and the minimum in Casuarina soils.

The available Nitrogen content in the top soil was 1277 kg/ha in Acacia, 1165 kg/ha in Eucalyptus, 1098 kg/ha in Casuarina, 874 kg/ha in barren laterite and 963 kg/ha in barren laterite with coal cinders. There was a reduction in the available Nitrogen content as the soil depth increased in all the treatments. All the three species caused an increase in the available Nitrogen content of the soil, the highest being observed in Acacia auriculiformis followed by Lucalyptus tereticornis.

The available Potash content of the soils did not record any change under the different species.

The available Phosphorus contents of the top soils were 92.7 kg/ha in Casuarina, 90 kg/ha in Eucalyptus, 81.5 kg/ha in Acacia, 79.3 kg/ha in barren laterite and 87.4 kg/ha in the barren laterite with coal cinders. There was reduction in the content of the nutrient as depth increased in all the treatments. In Acacia soils the content of the available Phosphorus had decreased.

Regarding the general observations, Acacia auriculiformis howed pronounced branching habits while Eucalyptus and Casuarina had more or less clean boles. Pests and diseases were not observed excepting the pink disease (c.o. Corticium salmonicolor) in Eucalyptus. Crows and rodents were the principal representatives of wild life in the plantation. Honey bees commonly foraged the inflorescence of Acacia.

Acacia auriculiformis proved itself to be a highly promising tree for energy plantations and for afforesting sites dumped with coal cinders and for sites offering little protection from anthropogenic influences and grazing. It also improved the organic matter content and available nitrogen content of the soil and was free from graziers. But at the same time there were also unwelcome effects due to Acacia such as increasing the acidity of the soil and supressing undergrowth. It also tended to be highly branching.

Eucalyptus tereticornis also was found to be good in growth and biomass production and could be recommended for similar sites. The species also enriched the soil by increasing the contents of organic carbon and available Nitrogen. Though it too reduced the pH of the soil, the species was found to support luxurient undergrowth and was spared by graziers.

Casuarina equisetifolia was a less suitable species for such a site as seen from the performance of the species. It suffered heavily from browsing and showed lesser survival growth and yield. But the species increased the organic carbon content and available Nitrogen content of the soil and permitted luxurient undergrowth especially grasses.