STUDIES ON GROWTH PERFORMANCE AND SITE AMELIORATION UNDER HIGH DENSITY PLANTATIONS

THESIS

By

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D E D I C A T E D T O

M Y

A D O R A B L E P A R E N T S

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C E R T I F I C A T E - I

It is to certify that the thesis entitled "Studies on growth performance and site amelioration under high density plantations" submitted for the degree of MASTER OF SCIENCE in FORESTRY (SILVICULTURE AND AGROFORESTRY) of Dr.Y.S.Parmar University of Horticulture and Forestry, is a record of the bonafide research work carried out by Mr.Ajay Sharma son of Sh.O.P.Sharma under my supervision and that no part of this thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of investigation have been fully acknowledged.

Solan

Dated 24.10.1989

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C E R T I F I C A T E - II

This is to certify that the thesis entitled "Studies on growth performance and site amelioration under high density plantations", submitted by Mr.Ajay Sharma to Dr.Y.S.Parmar University of Horticulture and Forestry, in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE in FORESTRY (SILVICULTURE AND AGROFORESTRY) has been approved by the student's Advisory Committee after an oral examination on the same in collaboration with the nominee of the Dean.

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A C K N O W L E D G E M E N T S

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(Ajay Sharma)

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Dated

C O N T E N T S

INTRODUCTION

Forests - a renewable resource, constitute an essential asset of a country owing to their significance in socio-economic development and enhancing the quality of environment. Unfortunately forest wealth in India is today faced with a near crisis situation. On one hand it is shrinking at an alarming pace - jeopardising the very life support system; on the other, growing population has increasing expectations of fuelwood, food, fodder and variety of other products from forests. The effective forest cover which should be around one third of the total landmass of the country has dwindled from 22.7 per cent in 1952 to 16.8 per cent in 1976 and 14.1 per cent in 1982 (Tandon, 1989). The over exploitation of trees is still not stopped as the country is loosing nearly 1.5 million ha of forest area every year (India Today, 1986). The productivity of the stands has made no headway but continues to rank much below (0.5 m^3 ha^{-1} yr^{-1}) as against the world average of 2.5 m^3 ha^{-1} yr^{-1}. The growing stock statistics of 32 m^3 ha^{-1} in comparision to world average of 110 m^3 ha^{-1} are also likewise very depressing (Bachkheti, 1982).

Undoubtedly, this eco-degradation is the outcome of escalating demographic pressures and our inability to maintain harmony between development and conservation. Today the country is faced not only with wide spread shortage of forest based products, but also with many concomitant environmental disasters. The recurrence of floods, droughts and landslides has become a common feature. The intensity of soil erosion and environmental pollution has attained almost appalling dimensions. A recent estimate of the Planning Commission reveals that the country has lost around 105 m ha under wasteland which amounts to 18-20 per cent to the total soil loss at the global level. It also projects a colossal gap between demand and supply of forest products by 2000 AD as the requirement for fuel wood, timber and pulp wood will increase by 19, 106 and 323 per cent respectively over what it was in 1980 (Khoshoo, 1986).

A perusal of the situation stated above reveals that there is an urgent need to evolve strategies which help in reducing the gap between demand and supply of forest products and revamping of the much degraded ecosystem. Attempts are needed not only to increase the productivity of existing stands but also to lessen the pressure on these, by raising massive plantations of the fast growing superior tree species. The culture of high density short rotation plantations, first proposed by McAlpine <u>et al</u> (1966), seems to hold a viable potential in this direction, such plantations would avoid the excessive drain of forests through generating ample quantum of wood to meet fuel, fibre and pulp requirements. The productivity of such plantations, however, shall depend largely on the nature of tree species, plant spacings, exploitable cycle, intensity of mangement and species adaptability to site. The fast growing species like Leucaena leucocephala, Melia azedarach and Eucalyptus hybrid which exhibit appreciable yields, shall account much preference in raising such plantations.

Eucalyptus, a native to Australia which belongs to family Myrtaceae has about 600 known species. The species exhibit rapid juvenile growth, best coppicing power, easy establishment, wide adaptability and outstanding biomass production. Since its introduction at Nandi hills (Mysore) in early eighties of 18th century it is utilized for shelter belts, wind breaks, essential oils, rutin and oxalic acid content and wood for pulp, transmission poles, fence-posts, manufacture of hard boards and particle boards, match splints, packing cases, timber, firewood and excellent charcoal (Chaturvedi, 1983).

Leucaena leucocephala (Fam. - Mimosaceae) is a prolific producer of highly palatable and nutritious leaves, flower buds, pods and twigs (Takahashi and Ripperton, 1947; Hall,1971). The light coloured and strong wood can be very well utilized for tool handles, tent pines, fence posts and possibly even for sports goods (Shukla, 1982; Bhalla and Sharma, 1982). In the process of improving soil, besides addition of significant amount of calcium and other micro nutrients, it adds 500 kg N, 200 kg P_2O_5 and 450 kg K_2O ha^{-1} yr^{-1} (Mendoza and Semana, 1976). Apart from these, Leucaena has immense value as props in Banana plantations, nurse and cover crop, hedge fence, soil conservation, green manuring, gum, medicine and other such miscellaneous uses (Krishnaswamy, 1956; Arora, 1979).

Melia azedarach, a member of family Meliaceae, is indigenous to Jhelum Valley (Kashmir) and is grown throughout the country as avenue and ornamental tree because of its attractive flowers (Seth *et al*, 1962). In addition to this its wood is also quite hard and it yields very attractive veneers. It is extensively used for toys, small boxes, handles of tennis racquets and also as small roofing material (Brandis, 1906).

The concept of high density short rotation plantations has attracted wide attention in many developed countries (Sancier *et al*., 1972; Steinback *et al*., 1972; Schmidt and DeBell, 1973; Cromer *et al*., 1976; Hansen and Backer, 1979; Cannel and Smith, 1980). In relation to biomass production, the yields as high as 19.7 dt/ha/yr with 22000 trees of populus clones over a period of seven years (Bowersox and Ward, 1976); 30 dt/ha/yr with 6470 stems for *Eucalyptus regnan* at 10 years (Frederick *et al*., 1983); 20 dt/ha/yr for *Acacia dealbata* at 8 years and 20 dt/hayr to over 30 dt/ha/yr in *Gmelina arborea* at 4th, 5th and 6th year (Akachuku, 1981) have been demonstrated. Although intensive studies on growth and yield of such plantations in India are still lacking, yet, the investigations of Seshadri *et al.*(1978) and Kimothi *et al.* (1983) provide some interesting information. In view of the pavcity of sufficient information on this aspect, the present investigation entitled "Studies on growth performance and site amelioration under high density plantation" was undertaken with the following objectives:

i) To study relative growth and biomass production potential of different species under various densities.

ii) To determine the effect of these plantations on site.

2. REVIEW OF LITERATURE

Eversince McAlpine *et al*. (1966) first proposed the idea of "Silage Sycamore" the concept of high density short rotation plantations has been gaining increasing attention. The system basically aims at producing increasing amount of wood on short cycles from the view point of pulp, fibre and fuelwood. Ribe (1974), Howlett and Gamache (1977) and Cannel and Smith (1980) have provided a comprehensive review on the work related to short rotation forestry. This approach has though attracted a number of investigations in industralised countries (Herrick and Brown, 1967; Steinbeck *et al*., 1968; Young, 1972; Steinbeck *et al*., 1972; Schmidt and DeBell, 1973; Pearce, 1983), the studies on these lines in India are still in the formative stage. There have been very few attempts to explore the biomass production potential of species when raised under varying spacings and different edapho-climatic conditions. The species influence on site with respect to soil-changes have been scarcely investigated. This chapter reviews the relevant literature pertaining to the performance of species under different spacings and species influence on site characteristics. For the sake of convenience the review has been discussed under the following three headings:

i) Growth performance and biomass productivity

Eucalyptus tereticornis

Leucaena leucocephala

Melia azedarach

ii) Plant nutrient content

Eucalyptus tereticornis

Leucaena leucocephala

Melia azedarach

iii) Species influences on site

2.1 Growth performance and biomass productivity

Eucalyptus tereticornis

Bhatia (1980) tried various combinations of spacing viz. 1.5m x 1.5m, 2.5m x 2.5m and 3m x 3m with number of irrigations and manurings to estimate growth potential in *Eucalyptus tereticornis*. Both, plant height and collar diameter were inversely related with plant density. Highest productivity (20 metric tonne ha^{-1} yr^{-1}) at the age of 2 years was observed at 3m x 3m spacing coupled with 2 baskets FYM per pit and four irrigations.

Shukla and Rajput (1981) estimated specific gravity of Eucalyptus species from different localities and found that there was large variation in the relative density of *Eucalyptus tereticornis* of different ages as well as among different trees of same age. Specific gravity ranged between 0.515 to 0.599 for the samples taken from the collar region of tree.

George (1982) observed average height 14.64m and average dbh 11.1cm in Eucalyptus hybrid plantations of East Dehradun Division at the age of 5 years. Thereafter at the age of 10 years, average height and average dbh were 18m and 14.4cm respectively. He estimated litter production at 5 years age and observed that 2567 Kg ha^{-1} leaf, 647 Kg ha^{-1} twig and 163 Kg ha^{-1} bark constituted 3377 Kg ha^{-1} of total litter biomass.

Patel (1982) reported total biomass yield of 38072 Kg ha^{-1} in Eucalyptus tereticornis; out of which 29942 Kg ha^{-1} was utilisable biomass, contributed by wood, bark and branches amounting to 12898, 4435 and 7609 Kg ha^{-1} respectively. Further 4761 kg leaf ha^{-1}, 15 Kg fruit ha^{-1} and 5336 Kg roots ha^{-1} were also included in total biomass.

Singh (1982) estimated above ground biomass production of Eucalyptus tereticornis in terms of mean annual net production to be 18.53, 16.16 and 27.27 ton/ha at the age of 5, 7 and 9 years respectively. Whereas under-ground biomass production was 2.11, 1.55 and 2.06 ton/ha during the same ages respectively.

Chauhan et al. (1983) investigated the effect of fertilizers and spacing on tree size, wood specific gravity and fibre length of 8 year old Eucalyptus tereticornis in Gujrat and W. Bengal. They concluded that close spacing adversely affected the height and girth of the trees whereas spacing and fertilizers showed no significant effects on specific gravity.

Gogate (1983) raised _Eucalyptus tereticornis_ under high density energy plantation in Gujrat and expected 5-6 times more yield per unit area when adequate sunlight, soil nutrients and moisture is assured. He revealed that when spacing increases from 1.75 sqm to 8 sqm, m.a.i. goes on decreasing. For economic returns 10' x 3' spacing is far better over 6' x 1', 6'x 2', 6' x 3' spacings. The 6' x 4' spacing showed outstanding performance from productivity point of view.

Gurumurthi _et al_. (1984) investigated biomass production and growth in _Eucalyptus hybrid_ under energy plantations trial (1.3m x 1.3m spacing) at six months interval in Gujrat. The results showed that the total biomass ranged from 5dt/ha at 12 months to 66.5 dt/ha at 36 months; the utilizable biomass (wood, bark and branch) ranged from 2.25 dt/ha to 43.5 dt/ha for the same period. They further revealed a direct correlation between the leaf biomass and total biomass of different categories of trees.

Nkaonja (1985) tried 93 species in Malawi, over 200 hactare of land in 1979. He observed that _Eucalyptus camaldulensis_, _Eucalyptus hybrid_, _Melia azedarach_ and _Leucaena leucocephala_ were among the best adapted and more productive species.

Pandey (1987) compared production potential of 17 species of humid tropics, tropical high land and semi-arid areas. Among the 8 species of semi-arid areas _Eucalyptus microtheca_ topped in wood production with wood m.a.i. of

7-10 Cu.m per hactare at 8-10 years age; Azadirachta indica showed wood ma.i. of 4-6 Cu.m ha^{-1} at same age. He further stated that Eucalyptus tereticornis planted on good sites in India attains maximum ma.i. of 15.5 Cu.m ha^{-1} at eight years age with 1200 stems ha^{-1} and 21 Cu.m ha^{-1} at six years age with 2900 stems ha^{-1}.

Tandon et al. (1988) observed that with increase in plant density dbh falls whereas plant height shoots up and usually, above ground biomass is 3-5 times of under ground biomass. They recorded mean height of 13.85m, mean dbh 8.6 cm in Eucalyptus tereticornis at 3 years age under a plant density of 1700 plants ha^{-1}. Further splitting the total biomass of 26.55 Kg $tree^{-1}$ produced in a diameter class of 6-10 cms at 3 years age, the share of various plant parts was recorded as 14.67 Kg stem, 2.16 Kg bark, 1.3 Kg leaf, 1.7 Kg twig, 3.25 Kg branch and 3.47 Kg roots.

Leucaena leucocephala

Brewbaker (1975) reported that Leucaena leucocephala at 16 years age attained a height of 20m or more in Guaitemala. Hawaiian gaint reached 15m height for the same age in Hawaii.

Anon.(1977) reported that Leucaena leucocephala when spaced every 4' as wind breaks, grew to a height of 4.1m in six months, 9.1m in 2 years and 16.8m in 6 years. In another single row planting of Gaint Leucaena leucocephala spaced at 1.2m, the dbh averaged 21.6cm with a range of 10.4 to 32.3cm in 6 years.

Benge (1978) reported that gaint Leucaena grew 13m tall with average dbh of 37cm in 8 years. Where as Gupta (1980) observed that in North India, Leucaena plants grow upto a height of 2m in first year and put on an average height increment of about one metre per year.

Hu et al. (1980) evaluated the growth of Leucaena in Taiwan and concluded that more wood can be produced by closer spacings. They found 20.06 cu.m ha^{-1} yield of Hawaiian gaint Leucaena with 40,000 trees ha^{-1}, 17.66 cu.m ha^{-1} with 20,000 trees per hactare and 12.27 cu.m ha^{-1} with 10,000 trees per hactare of one year old plantation.

Pathak et al. (1980) studied the effect of three population densities (4, 3 and 1.5 plant/sq.m) there cutting intensities (10, 20 and 30cm above the ground) and three cutting intervals (40, 60 and 120 days)on the forage yield of *Leucaena leucocephala* . The maximum forage yield was obtained with 40 days interval, 30cm cutting height and the highest population density (4 plants/sq.m). Dry matter per hactare was reduced with depression in plant density. Production of branches and leaf/stem ratio was enhanced with decrease in plant density.

In Jammu-Tawi, Dutt (1981) observed that Leucaena attained a mean height of 4.58m and mean dbh of 2.65cm in the first 9 months. Leucaena tree, however, attained a height of 7.02m and dbh 5.35cm in 2 years.

Kapoor *et al*. (1981)reported average height of 3.04m, collar diameter 3.2cm and dbh 1.55cm in 18 months for *Leucaena leucocephala* under Dehra Dun conditions.

Under farm forestry conditions, aerial biomass and coppice shoot growth performance of *Leucaena leucocephala* were observed by Pathak *et al*. (1981). They revealed that under 3 rows at 2m spacing, 11.0 ton fuel wood and 1 ton fodder (on dry matter basis) can be produced on per hactare basis. They also observed 5.59m average height, 5.16cm average dbh, 5.18 Kg average biomass of bole and branches per tree and 0.749 kg leaves per tree making a total of 5.929 kg aerial biomass per tree at 3 years age.

Shukla (1982) conducted some physical and mechanical tests on the strength properties of *Leucaena leucocephala* in green condition in Tarai forest of Distt. Nainital. They recorded the average specific gravity to the tune of 0.601.

Van Den Beldt *et al*.(1982) indicated the productivity of *Leucaena leucocephala* at 4 years age to the tune of 13.3 to 54.9m^3 ha^{-1} yr^{-1} at a density of 5,000 trees ha^{-1}. They recorded the yield of 96.8 m^3 ha^{-1} yr^{-1} at 10,000 trees ha^{-1} density in 3 years.

Chaturvedi (1983) viewed the performance of Leucaena at different densities. He recorded average dbh of 8.9cm and average height of 11.3m at the age of 2.5 years in 2m x 2m spacing. At the same age, using 3m x 3m spacing, he observed average dbh 9.5cm and average height of 10.8m and concluded that plant height was reduced where as dbh was enhanced with reduction in plant population.

Relwani *et al.*(1984) conducted an experiment on *Leucaena leucocephala* under various plant densities at Uruli-Kanchan in 1972. They estimated fodder yield, growth and productivity at the age of 9½ years. They observed largest fodder yield of 72.96 q ha^{-1} cutting^{-1} at a density of 1,00,000 plants ha^{-1} followed by 66.83 q ha^{-1} cutting^{-1} at 50,000 plants ha^{-1} and 62.26 q ha^{-1} cutting^{-1} at 33333 plants ha^{-1}. They revealed a linear relationship of yield with increasing density. It was further observed that plants in 1m x 1m spacing averaged a height of 10.46m and dbh of 6.59cm against 10.94m in height and 12.7cm dbh in 3m x 3m spacing in 3 years.

Mishra *et al.*(1986) dealt with biomass accumulation pattern in *Leucaena leucocephala* K-8 raised under 0.75m x 0.75m, 1m x 1m, 1.25m x 1.25m and 1.50m x 1.50m spacings. Maximum biomass was recorded in plants raised at 1.25m x 1.25m spacing. Accumulation of dry matter (kg per plant) revealed a direct relationship with increasing spacement, whereas total biomass production followed an inverse trend with increasing spacings. Maximum value for both, average height and average diameter were observed under 1.25mx 1.25m spacing, revealing a positive response to wider spacings.

Pathak (1987) tried Leucaena at various sites including dry and moist conditions. On road side (moist) plantation at 4 years age with 5,000 plants ha^{-1} density, collar diameter was 12.5 $\pm$ 1.2cm, height was 12.4 $\pm$ 0.9m yielding 308 cu.m ha^{-1} volume. On river bank (moist) at the age of 7 years under same plant density, collar diameter was 16.8 $\pm$ 1.6cm, height 18.1 $\pm$ 0.8m yielding 837.6 cu.m ha^{-1} of volume. Even on dry road side plantations in 4 years appears to be encouraging for optimizing biomass production from waste lands.

Sharma *et al.*(1987) while comparing the growth performance of eleven agroforestry species, observed 113.65cm height and 0.81cm collar diameter at 6 months age in *Leucaena leucocephala* . It gave quite better performance than *Eucalyptus tereticornis* which attained 84.92cm height and 0.85cm collar diameter within same period of time.

Desai *et al.*(1988) tried *Eucalyptus hybrid* and *Leucaena leucocephala* under 30cm x 30cm, 60cm x 60cm and 90cm x 90cm spacings to estimate annual yields. Highest yield of Leucaena was recorded under 60cm x 60cm spacing whereas the maximum biomass under *Eucalyptus hybrid* was observed at 90cm x 90cm spacing.

Melia azedarach

Anon. (1970) revealed the performance of *Melia azedarach* to be better than *Poinciana regia* and *Albizzia procera* .

In Maharashtra, 8 species were tried on degraded vertisols by Nimbkar *et al.*(1986). At 15 months age, Leuceana leucocephala and Melia azedarach were found to be superior than all other species. These two species performed better at the spacing of 5m x 0.6m as compared to 3m x 1m.

Watanabe et al. (1988) advocated the use of Eucalyptus camaldulensis, Melia azedarach and Leucaena leucocephala in Thailand, under Taungya system with various crops viz. coffee, cashew nut, banana, etc. They considered these as fast growing species and best suited to all the four agro-climatic zones of the country.

Miscellaneous

Fakirov (1972) estimated the biomass production of poplar plantations under different spacings varying from 3m x 3m to 8m x 8m. After 7 years, best growth performance was observed at spacing of 4m x 4m.

Heilman et al. (1972) tested 0.30m x 0.30m, 0.61m x 0.61m and 1.22m x 1.22m spacing in close spaced, short-rotation culture of black cotton wood. They concluded closest spacing (0.30m x 0.30m) resulted in highest yield in the first rotation where as in the second rotation, yield was not affected significantly by spacing. In both the rotations dry matter production ha^{-1} followed an inverse trend with increase in spacing.

Palashev (1973) detailed the performance of Populus deltoides upto the age of 12 years under various plant densities. Stem wood volume per hactare at the age of 12 years decreased with increasing spacing. However, m.a.i. was 4.84cu.m

ha^{-1} at 2m x 2m spacing and 2.38 cu.m ha^{-1} for 6m x 6m spacing.

Schmidt and Debell (1973) grew populus under 0.3m x 0.3m, 0.6m x 0.6m and 1.2m 1.2m spacings. At the age of 2, 3 and 4 years, maximum wood production was observed under 0.6m x 0.6m spacing followed by 0.3m x 0.3m and then by 1.2m 1.2m spacing.

Dawson *et al*. (1976) studied growth, dry weight yield and specific gravity of 3 years old *Populus* 'Tristis#1' under intensive culture and suggested that more wood can be produced for pulp manufacture under short rotation and nearly optimal growing conditions than in natural stands.

Kaul and Sharma (1982) planted *Pinus caribaea* under different spacings varying between 2 sq.m to 3.5 sq.m and observed its growth at the age of 8-9 years. DBH was enhanced with increase in plant spacing where as plant height and mean plot volume followed an inverse trend with plant spacings.

Kaul *et al*.(1983) observed that at the age of 8 years,438 poplar trees yielded 85991 kg per hactare biomass in total. Share of various tree components was estimated in the order :bole (48-59 %); leaf (5-8%); Bark (11-18%); branches (8-19%) and twig (10-17%). The above ground biomass shared 83 per cent and roots shared 17 per cent of the total biomass.

2.2 Plant nutrient content

Eucalyptus hybrid

George (1984) investigated biomass production and nutrient removal in three,10 year old plantations of *Eucalyptus hybrid* . He observed that biomass production was 93187 kg ha^{-1} with 992 trees ha^{-1}, 9868 kg ha^{-1} with 1023 trees and 83804 kg ha^{-1} with 1133 trees ha^{-1} which constituted 69-74 per cent of the total above ground biomass of the total uptake 43-44 per cent of N, 48-50 per cent of P, 31-35 per cent of K and 37-47 per cent of Mg were removed by wood harvesting alone. 12-30 per cent of the total uptake of various nutrients could be re-cycled by leaving the bark on forest floor.

Gupta and Raturi (1984) observed 1.78 per cent N, 0.087 per cent P, 0.91 per cent K, 1.357 per cent Ca and 0.308 per cent Mg in leaves of *Eucalyptus hybrid* at 10 years age. Bark recorded 0.41 per cent N, 0.033 per cent P, 0.522 per cent K, 3.4 per cent Ca and 0.293 per cent Mg where as 0.383 per cent N, 0.027 per cent P, 0.353 per cent K and 0.947 per cent Ca and 0.150 per cent Mg was indicated in branches. However, 0.19 per cent N, 0.023 per cent P, 0.108 per cent K, 0.210 per cent Ca and 0.023 per cent Mg was revealed in bole.

Negi and Sharma (1984) reported that in *Eucalyptus globulus* harvesting the bole alone (59per cent of the total biomass) at the age of 7 years resulted in the removal of nearly 44 per cent N and P, 29 per cent K, 7 per cent Ca and 24 per cent Mg.

Singh (1984) recorded nutrient concentrations in different plant parts of 5 year old *Eucalyptus tereticornis*. He observed 0.96 per cent N, 0.29 per cent P and 4.58 per cent Ca in leaves, 0.51 per cent N, 0.24 per cent P and 3.83 per cent Ca in bole, 0.46 per cent N, 0.23 per cent P and 3.50 per cent Ca in branches, 0.28 per cent N, 0.29 per cent P and 3.75 per cent Ca in roots.

Malik (1987) estimated nutrient content in various plant components. In leaves 1.307-1.643 per cent N, 0.180-0.207 per cent P and 0.42-0.58 per cent K were highest among all tree components. In branches, N (0.560-0.747 per cent), P (0.105-0.183 per cent) and K (0.37-0.48 per cent) was observed where as 0.597-0.747 per cent N, 0.128-0.188 per cent P and 0.42-0.48 per cent K were reported in stem. However, in roots 0.485-0.709 per cent N, 0.070-0.117 per cent P and 0.37-0.44 per cent K were recorded.

Leucaena leucocephala

Upadhyay *et al.*(1974) found a wide ratio between calcium and phosphorus (16:1) i.e. Calcium (2.7 per cent) and Phosphorus (0.17 per cent) in mature *Leucaena leucocephala* leaves. Where as magnesium 0.11-0.32 per cent, Phosphorus 0.10-0.25 per cent and calcium 1.2-2.2 per cent have been reported by James *et al.* (1977).

Adenge (1979) reported 2.8 per cent calcium, 0.20 per cent phosphorus, 1.78 per cent potassium, 0.21 per cent sodium and 0.37 per cent magnesium in mature leaves of Leucaena.

According to Sharma (1981) dry Leucaena contains total ash 11.0 per cent, total nitrogen 4.2 per cent, Calcium 2.3 per cent and phosphorus 0.23 per cent.

<u>Melia azedarach</u>

Singh (1982) reported 2.55 per cent calcium and 0.23 per cent phosphorus in <u>Melia azedarach</u>, while in <u>Leucaena leuçocephala</u>, 2.99 per cent calcium and 0.19 per cent P was reported.

<u>Miscellaneous</u>

Kaul <u>et al</u>. (1979) estimated nutrient content (N, P, K, Ca and Mg) of leaves, twig, branches, stems and bark in 21 year old coppiced <u>sal</u> forest. They observed highest concentration of N, P, K, Mg in leaves and Ca in bark. Highest value of N, P, K and Mg in leaves was followed by twig, bark and bole where as highest value of Ca in bark was followed by twig, leaves and bole.

2.3 Species influences on site

Trees can have a major effect on site by influencing micro-climate and soil properties. They affect the soil primarily by the amount and composition of litter deposited and also by nutrient uptake and accumulation. They also affect the amount and composition of water flow into and through the eco-system. In some cases tree species enriches the soil by fixing atmospheric-N_2, where as in others only the nutrient depletion is accounted. Since the information on this aspect is very scanty, it is attempted to present the relevant literature in a condensed form.

Dijkman (1950) revealed that the nutrients which Leucaena obtains from the deeper soil strata are gradually deposited in the top soil as it sheds leaves regularly. It was further found that the amount of organic material can be increased enormously.

Nihlgard (1971) observed soil chemical properties under 40-55 years old Picea abies surface soil pH, Ca, Mg and K were some what lower; P and Fe were some what higher, and N and C were the same as under Fagus sylvatica .

Anon.(1976) mixed Leucaena glauca, after one year of sowing, into the soil and revealed that alkaline soil has become neutral.

Flinn et al. (1979) reported a net annual increase of nutrients per hactare for three undisturbed forest catchments distant from coast, of the order of 0.3kg N, 0.005 kg P, 2.7 kg Ca, 1.4 kg K, 0.2 kg Mg, 1.0 kg Na and 9.9 kg Cl.

George (1979) estimated that in Eucalyptus hybrid plantation of 6 year age, 18.5 kg ha^{-1} of K, 18.5 kg ha^{-1} of Ca, 4.7 kg ha^{-1} of Mg, 3.9 kg ha^{-1} of N and 0.4 kg ha^{-1} of P is returned to the soil as stenflow, through fall and rain water.

Turvey (1979) found that depletion of exchangeable calcium in the soil under 4 year old and 14 year old

Eucalyptus hybrid.plantations corresponded very closely to the quantity of calcium contained in the biomass. His data showed that the harvesting of the 14 year old plantation could leave the soil severly depleted in exchangeable calcium.

Wise and Pitman (1981) observed Phosphorus, Sulphur and Calcium to be the main limiting nutrients for forest trees in New South Wales. Nitrogen might also be limiting on a few sites but in most forest situations nitrogen availability usually increases after clear felling (harvest).

Evans and Rombold (1984) observed that Melia azedarach if clearfelled after 10 years age, have a potential to improve soil by adding organic-C and nitrogen. Besides improving soil aeration, its root retriev the nutrients leached below the root zone of annual crops. It was observed that humus layers was re-built and the soil structure is becoming less compact and more porus where wood lots have been planted.

Karunakaran (1984) conducted a study at Kerala Forest Research Institute to evaluate the change in soil properties under current Eucalyptus plantations. The study indicated generally high fertility of the soils, based on relatively higher levels of organic carbon and cation exchange capacity.

Singh (1984) revealed that Ca concentration was 7-8 times to that of nitrogen in 5-9 years old Eucalyptus hybrid. The ratio was still higher in non-leaf litter. Eucalyptus tereticornis released 14.25 to 34.59 kg N, 98.22 to 334.55 kg Ca and 8.63 to 13.78 kg P $ha^{-1}yr^{-1}$ to soil in 5-9 years old plantations.

Verinumbe (1987) received highest ground nut yield on the soil from under Azadirachta indica followed by Prosopis foliflora, Eucalyptus camaldulensis and field soils.

3.

MATERIALS AND METHODS

The present investigation entitled "Studies on growth performance and site amelioration under high density plantations", was carried out in the energy plantation trial at Regional Research Station, Dhaulakuan (Sirmaur) of the Dr.Y.S.Parmar University of Horticulture and Forestry, Solan Himachal Pradesh during the year 1988-89. Details about the experimental site, materials used and methodology adopted during the course of study are discussed in this chapter.

3.1 Experimental site

3.1.1 Location

The experimental site is located at 30°4'N latitude and 77°5'E longitude with elevation of 370 metre above mean sea level. It is situated at a distance of 22 Km from Nahan on Nahan-Dehra Dun road.

3.1.2 Climate

The study area falls in the sub mountain low hill sub-tropical zone. May and June are the hottest months whereas December and January experiences the lowest temperatures. Both early as well as late frosts are quite common. On an average the annual rainfall varies from 1400-1800mm, most of which is concentrated during July-August (Monsoon season). Winter showers are though common, but the quantum of precipitation is usually low. Annual temperature

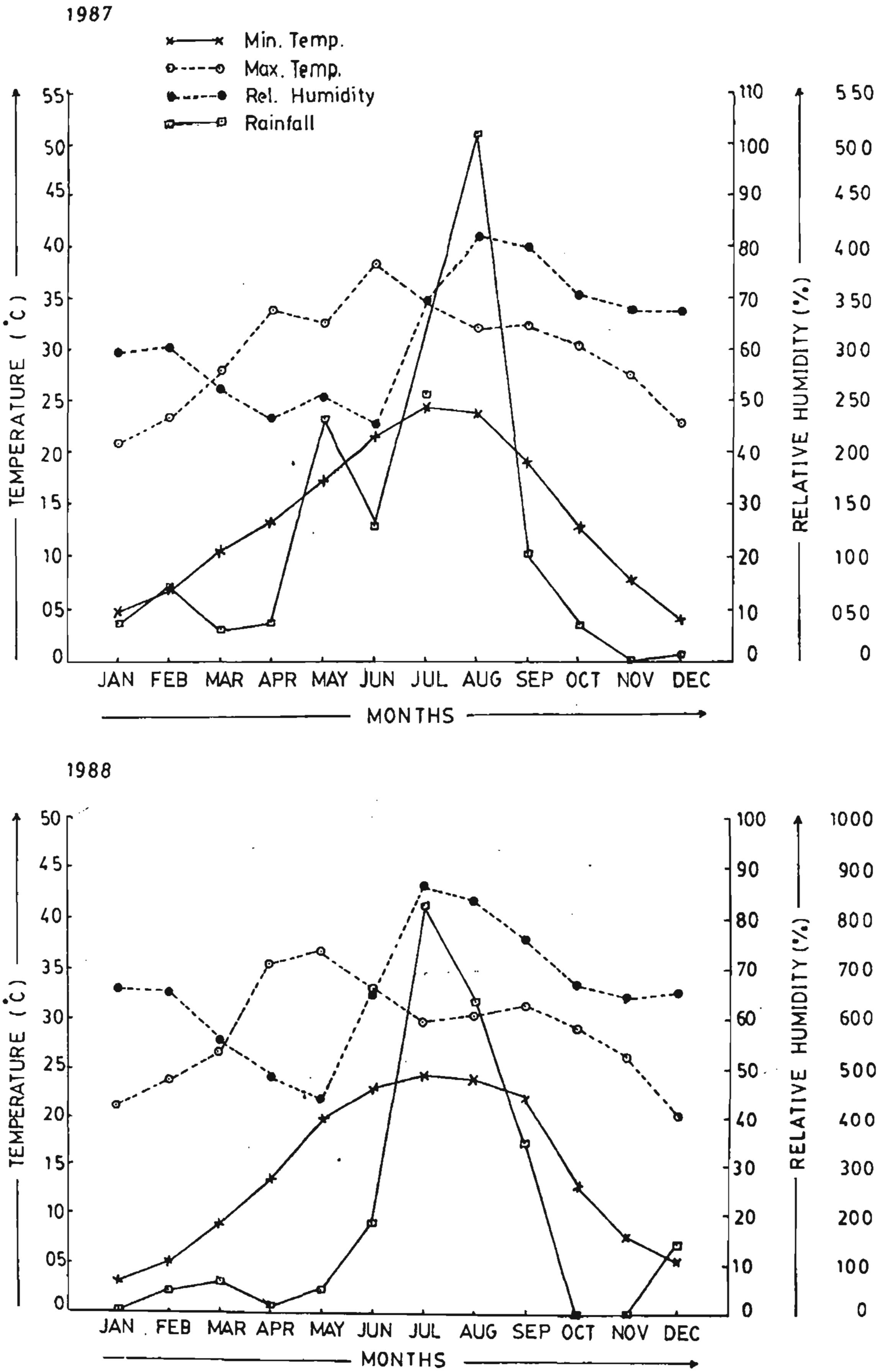

Fig. 1. Metrological Data for Regional Research Station, Dhaulkuana. for the Year_1987 Aand 1988.

range between 4-44°Celsius with a mean value of 23.5° Celsius. The meteorological data pertaining to the experimental site for the year 1987 and 1988 are presented in appendix -I and graphically illustrated in Fig.1.

3.1.3 Soil characteristics

The experimental site was an abandoned land on the bank of seasonal rivulet. Due to low depth of soil and high proportion of gravel, it was being used only for grazing and at times for storing the fire wood and agricultural produce. The details of the profile characteristics as well as chemical analysis for soil samples drawn before initiating the study are documented in Table 1a and 1b respectively.

3.2 Description of energy plantation trial

The energy plantation experiment was established during July 1986 to demonstrate the growth and biomass production potential of three fast growing species under varying plant densities. In total 960 plants for each of the species i.e. *Eucalyptus hybrid*, *Melia azedarach* (non leguminous spp.) and *Leucaena leucocephala* (leguminous) were planted originally. These species showed remarkable establishment as an average survival of more than 98.7 per cent was noticed at the time of recording observations i.e. October, 1988. The full details about the experimental design, layout and treatments are mentioned in the following sections.

Table 1a : Soil profile characteristics of the experimental area

Land features - Flat land

Parent materials- Sand-stone, Conglomerates, boulders, pink dolomitic lime-stone and calcareous shales

Horizon	Depth	Characters
A_1	0 - 15cm	Tex: Sandyloam; str: weak medium sub angular blocky; Colour : 10 YR 5/4
A_3	15 - 30cm	Tex: Sandyloam; Colour: 10 YR 4/4
B	30 - 70cm	Tex: Loamysand; Colour 10 YR 4/4
II C_1	70 - 90cm	Tex: Sandyloam; colour: 10 YR 5/4

Table 1b: Soil chemical characteristics of the blank area adjoining to the experimental area

Soil Depth	Characters
0 - 15cm	pH: 6.96; organic carbon: 0.22 per cent; available nitrogen: 306.55 kg ha^{-1}; available phosphorus: 26.8 kg ha^{-1}; available potassium: 119.4 kg ha^{-1}; exchangeable calcium: 618.33 ppm; exchangeable magnesium: 136.33 ppm.

3.2.1 Experimental design and layout

The experiment was laid out in a Factorial Randomised Block Design (RBD) with three replications. The treatments included three species and four densities comprising 12 combinations. The size of each plot was kept as 8 m x 8 m.

3.2.2 Treatments

The details of the 12 treatments resulting from all the possible combinations of three species and four densities are given below.

Species:

S_1 - Eucalyptus hybrid (Sym. E. tereticornis)

S_2 - Leucaena leucocephala

S_3 - Melia azederach

Spacings:

D_1 - 5, 000 plants/ha (2m x 1m)

D_2 - 10,000 plants/ha (1m x 1m)

D_3 - 15,000 plants/ha (1m x 0.66m)

D_4 - 20,000 plants/ha (1m x 0.5m)

Treatments:

S_1D_1	S_2D_1	S_3D_1
S_1D_2	S_2D_2	S_3D_2
S_1D_3	S_2D_3	S_3D_3
S_1D_4	S_2D_4	S_3D_4

3.3 Observations recorded

The observations were recorded on growth, biomass and nutrient content in plant component and chemical changes in soil component. To study growth related characters a definite sample proportional to plant population (density) i.e. 5 plants from 5000 plants/ha density and 20 plants from 20,000 plants/ha density was selected randomly. Biomass estimations, however, was performed by excavating only 5 plants from each plot. The observations were made from October 24 -28, 1988 when the years growth was almost complete. The details of the methodology adopted are as under:

Plant height

Plant height was measured in metres from ground level to the tip of main shoot with the help of a properly graduated wooden rod.

Collar diameter

Collar diameter was measured in centimeters with the help of a vernier calliper. To maintain uniformity, measurements were taken 5cms above ground level.

Specific gravity

Observations on specific gravity were confined to the main stem. Specific gravity was determined by the maximum moisture method (Smith, 1954). Two centimeter long samples of wood were taken at collar level. The green weight of the samples at maximum moisture level was recorded. The samples were then oven dried at $102 \pm 1^{\circ}C$ until a constant weight was attained; the dried samples were weighed and the specific gravity was worked out as per the formula given below:

$$\text{Specific gravity of wood sample} = \frac{1}{\frac{Mm-Mo}{Mo} + \frac{1}{GS}}$$

where

Mm = Fresh/green weight of the sample having maximum moisture content

Mo = Oven dry weight of sample

GS = a constant with a value of 1.53

Total biomass and its partitioning

To study this aspect, five plants were sampled from each plot. The plants were separated into different components viz. root, stem, branches and leaves and processed for green and dry weight measurements. Leaves and wood samples were oven dried at 60°C and 110°C respectively. Biomass of the component was worked out by using the formula

$$\text{Dry matter} = \frac{\text{Dry weight of samples}}{\text{Fresh weight of the samples}} \times \text{Total fresh weight}$$

Sum of the dry weight of all the components gave the total biomass.

3.4 Chemical analysis

3.4.1 Plants

The oven dried and ground plant samples were digested in 4:1 Nitric Perchloric acid mixture. The digested material was diluted to 100ml. Total Phosphorus and Potash were determined by Vando-molybdate method and flame photometer (Jackson, 1973) respectively. Total Ca and Mg content were determined by Versenate method (Richard, 1954). For the estimation of total N, plant material was digested in concentrated sulphuric acid and it was determined by Micro-kjeldahl method (Jackson, 1973).

3.4.2 Soils

The soil samples were analysed for the various chemical characteristics. Soil pH was determined in 1:2.5 soil water suspension with the help of digital pH meter. The organic carbon was estimated by wet digestion method of Walkley and Black (1934). Available N was determined by Alkaline Potassium permagnate method (Subbiah & Asija, 1956). The determination of available phosphorus was done by Olsen's method (1954). Available K was extracted in neutral normal ammonium acetate solution (Morwin & Peach, 1951) and estimated by a Flame Photometer. Exchangeable Ca and Mg were determined with EDTA titration method given by Black (1965).

3.5 Statistical analysis

The data recorded for different parameters were subjected to appropriate statistical analysis as per the procedure given by Cochran and Cox (1970) and ANOVA were prepared accordingly.

4.

E X P E R I M E N T A L R E S U L T S

The results of the present investigation undertaken to study the growth performance and site amelioration under high density plantations are presented in this chapter. The results have been dealt under five principal headings:

i) Survival

ii) Growth and development

iii) Biomass and its partitioning

iv) Plant nutrient content

v) Site amelioration

The relevent data pertaining to different attributes have been presented in Table 2 to 10. The analysis of variance have been appended in appendix-II.

4.1 Survival per cent

The data on survival per cent revealed only 1-2 per cent mortality (Table 2). The species, density as well as species x density interaction did not cause any significant effect on survival.

4.2 Growth and development

The results in relation to growth and development of different species raised under varying densities are presented in Table 2.

Table 2 Survival, growth and development in different species as influenced by various densities

Species	Survival per cent					Plant height (cm)					Collar diameter (cm)					Specific gravity				
	D_2	D_2	D_3	D_4	Mean	D_1	D_2	D_3	D_4	Mean	D_1	D_2	D_3	D_4	Mean	D_1	D_2	D_3	D_4	Mean
Eucalyptus hybrid	98.96	100.00	100.00	100.00	99.74	2.87	3.43	3.54	3.44	3.32	3.02	2.89	2.84	2.77	2.88	0.5723	0.5697	0.5672	0.5642	0.5684
Leucaena leucocephala	98.96	100.00	97.57	98.44	98.74	3.41	3.89	3.90	3.97	3.79	3.52	3.12	3.10	2.77	3.13	0.6493	0.6415	0.6356	0.6315	0.6395
Melia azedarach	98.96	100.00	99.65	99.48	99.52	3.04	3.32	3.37	3.76	3.76	4.51	3.61	3.31	3.26	3.67	0.4841	0.4677	0.4235	0.3933	0.4415
Mean	98.96	100.00	99.07	99.30		3.10	3.55	3.60	3.72		3.68	3.21	3.08	2.93		0.5677	0.5596	0.5421	0.5291	

SE_d	Survival per cent	Plant height	Collar diameter	Specific gravity
S	0.66	0.11	0.17	0.0091
D	0.76	0.13	0.19	0.0105
S x D	1.32	0.22	0.34	0.0182
C D at 5%				
S	NS	0.23	0.35	0.0189
D	NS	0.26	0.41	0.0219
S x D	NS	NS	NS	0.0379

4.2.1 Plant height

Plant height reflected significant differences among different species (Table 2). Leucaena leucocephala (S_2) registered the maximum plant height (3.79m) which proved significantly better than Eucalyptus hybrid (S_1) as well as Melia azedarach (S_3); the latter species, however, remained statistically at par. Plant height increased with increase in plant density. The D_2, D_3 and D_4 though revealed no significant differences yet proved statistically superior to D_1.

The species x plant density interaction showed no significant effect for plant height. In all the species, the plant height increased with an increase in plant density excepting for Eucalyptus hybrid where D_4 showed comparatively smaller plants than D_3.

4.2.3 Collar diameter

Table 2 shows that collar diameter in species ranged from 2.88 to 3.67cm. It gained the maximum value under S_3 which was significantly higher than other species. S_2 though depicted substantial gain over S_1, the difference, however remained statistically non-significant.

Collar diameter declined with increase in plant density. It attained significantly higher value under D_1 as compared to other densities; the D_2, D_3 and D_4 behaved statistically alike.

The collar diameter was not influenced significantly by interaction between species and densities. It attained

Table 3 Biomass and its partitioning (on kg per plant basis) in different species as influenced by various densities

Species	LEAF BIOMASS D_1	LEAF BIOMASS D_2	LEAF BIOMASS D_3	LEAF BIOMASS D_4	LEAF BIOMASS Mean	TWIG BIOMASS D_1	TWIG BIOMASS D_2	TWIG BIOMASS D_3	TWIG BIOMASS D_4	TWIG BIOMASS Mean	STEM BIOMASS D_1	STEM BIOMASS D_2	STEM BIOMASS D_3
Eucalyptus hybrid	0.26	0.25	0.21	0.18	0.22	0.105	0.085	0.063	0.061	0.078	0.39	0.37	0.36
* Per cent	27.08	28.08	26.25	23.38	26.37	10.94	9.55	7.88	7.92	9.18	40.63	41.57	45.00
Leucaena leucocephala	0.25	0.21	0.18	0.17	0.20	0.097	0.092	0.091	0.084	0.091	0.71	0.56	0.53
* Per cent	18.66	19.44	18.56	22.08	19.42	7.23	8.52	9.38	10.91	8.70	52.98	51.85	44.64
Melia azedarach	0.23	0.21	0.18	0.18	0.20	0.94	0.092	0.085	0.084	0.088	1.35	0.65	0.65
* Per cent	9.75	15.33	15.38	20.45	13.71	3.98	6.72	7.26	9.55	6.11	57.20	47.45	55.55
Mean	0.24	0.22	0.19	0.17	Mean 19.83	0.098	0.090	0.079	0.076	Mean 7.99	0.82	0.53	0.51

Species	STEM BIOMASS D_4	STEM BIOMASS Mean	ROOT BIOMASS D_1	ROOT BIOMASS D_2	ROOT BIOMASS D_3	ROOT BIOMASS D_4	ROOT BIOMASS Mean	TOTAL BIOMASS D_1	TOTAL BIOMASS D_2	TOTAL BIOMASS D_3	TOTAL BIOMASS D_4	TOTAL BIOMASS Mean
Eucalyptus hybrid	0.36	0.37	0.20	0.18	0.17	0.17	0.18	0.96	0.89	0.80	0.77	0.86
* Per cent	46.75	43.37	20.83	20.22	21.25	22.07	21.08					
Leucaena leucocephala	0.41	0.55	0.28	0.22	0.17	0.11	0.20	1.34	1.01	0.97	0.77	1.04
* Per cent	53.23	53.13	20.90	20.37	17.53	14.29	18.75					
Melia azedarach	0.42	0.77	0.69	0.42	0.25	0.20	0.39	2.36	1.37	1.17	0.88	1.45
* Per cent	47.73	53.65	29.24	30.66	21.37	22.73	27.13					
Mean	0.40	Mean 49.85	0.39	0.27	0.20	0.16	Mean 22.33	1.55	1.11	0.98	0.81	

SE_d	Leaf biomass	Twig biomass	Stem biomass	Root biomass	Total biomass
S	0.08	0.007	0.01	0.03	0.14
D	0.09	0.008	0.01	0.04	0.16
S x D	0.15	0.014	0.03	0.07	0.28
C D at 5%					
S	0.16	NS	NS	0.07	0.29
D	0.18	0.016	0.03	0.08	0.33
S x D	0.31	NS	NS	0.14	NS

the maximum value (4.51cm) for S_3 at D_1, whereas the minimum value (2.77cm) occurred for S_1 at D_4.

4.1.4 Specific gravity

The specific gravity varied significantly among different species (Table 2). It assumed the highest value in S_2 (0.6395) followed by S_1 (0.56684) and S_3 (0.4415). Plant density showed an inverse relation with specific gravity. The D_1 behaved statistically alike to D_2 but proved significantly better than D_3 and D_4. The D_2, and D_3 did not differ significantly.

Specific gravity was not found to be influenced significantly by species x plant density interaction. It experienced a continuous decline in all the species with increasing plant population; significant difference however could be noticed only in S_3 where D_1 and D_2 though remained statistically at par but were significantly better than D_3 and D_4. While observing the specific gravity of species under a particular density, the <u>Leucaena</u> <u>leucocephala</u> always excelled the other species.

4.3 <u>Biomass and its partitioning</u>

4.3.1 Biomass computed on per plant basis

The data on total biomass and its partitioning as computed on individual plant basis are presented in Table 3.

4.3.1.1 Leaf biomass

Leaf biomass in species ranged from 0.20 to 0.22 kg $plant^{-1}$ (Table 3) but lacked to reflect significant differences.

Leaf biomass revealed significant differences among different densities. It showed a consistent reduction in leaf biomass with increase in plant density. D_1 behaved statistically alike to D_2 but both the levels were found significantly better than D_3 and D_4. The leaf biomass was not influenced significantly by interaction between species and densities. It obtained the maximum value in case of S_1 D_1 whereas S_2 D_4 recorded the minimum value.

4.3.1.2 Twig biomass

The twig biomass varied from 0.079 to 0.091 kg $plant^{-1}$ in species but reflected no significant differences (Table 3). L. leucocephala accumulated the maximum twig biomass followed by Melia azedarach and E.tereticornis. There was a marked decline in twig biomass with increase in plant density. D_1 behaved statistically at par with D_2 but proved significantly better than D_3 and D_4. The D_2, D_3 and D_4 depicted no statistically significant differences.

The twig biomass was not found influenced significantly by species x density interaction. It decreased under all species with subsequent increase in plant density. Maximum as well as minimum twig biomass was observed for S_1 at D_1 and D_4 respectively.

4.3.1.3 Stem biomass

Stem biomass differed significantly among different species (Table 3). Maximum stem biomass was recorded in S_3 (0.77 kg plant^{-1}) whilst S_1 yielded the minimum value (0.37 kg plant^{-1}). Stem biomass depicted an inverse relation with plant density. It attained significantly higher value under D_1 as compared with other densities. Increasing plant density from D_2 to D_3 or D_4 resulted in considerable decline in stem biomass but the difference remained non-significant.

The stem biomass was affected significantly by species x density interaction. It decline, in general, under all species with corresponding increase in plant population. Significant reduction however could be observed only under S_3 while increasing the density from D_1 to D_2, D_3 or D_4. In relation to performance of species under a definite density, S_3 always maintained its superiority over other species.

4.3.1.4 Root biomass

As evident from Table 3 root biomass was influenced significantly by the species under study. It attained the maximum value in S_3 (0.39 kg plant^{-1}) which was significantly higher than S_2 (0.20 kg plant^{-1}) as well as S_1 (0.18 kg plant^{-1}); the latter species depicted no significant difference. Root biomass experienced a significant reduction with increase in plant density from D_1 to D_2, D_3 or D_4. The D_2 behaved statistically alike with D_3 but proved significantly better than D_4.

There was a significant effect of species x density interaction on root biomass. It declined in all the species with increase in plant density; a drastic decline, however could be observed only in Melia azedarach. While observing root biomass under a particular density it was seen, S_3 always maintained its superiority over other species.

4.3.1.5 Total biomass

Table 3 shows that total biomass production differed significantly among different species. Melia azedarach accumulated the maximum biomass 1.44 kg $plant^{-1}$ which was 27.7 per cent more than L. leucocephala and 39.58 per cent more than E.hybrid. L. leucocephala yielded 16.35 per cent more biomass than E. hybrid but the difference remained statistically non-significant.

Total biomass declined markedly with increase in plant density. There was a significant reduction of 28.57 per cent, 35.71 per cent and 46.75 per cent in total biomass with increase in plant population from D_1 to D_2, D_3 and D_4 respectively. The D_2, D_3 and D_4 behaved statistically alike.

The species x plant density interactions did not influence total plant biomass significantly. While comparing the performance of species under different densities, S_3 always yielded the maximum biomass followed by S_2 and S_1. While comparing the contribution of individual plant component in total biomass irrespective of densities, it was seen that both in E.hybrid as well as Leucaena leucocephala stem provided the major share followed by leaf, root and twig. In M.azedarach stem continued to be the dominant component but the root biomass showed an edge over leaf biomass. Average contribution of stem, root, leaf and twig computed on the basis of three species was observed to be 49.85, 22.33, 19.83 and 8.03 per cent respectively. There was apparantly more allocation of assimilates towards above ground portion in all the three species.

4.3.2 Total biomass computed on per hactare basis

The data on total biomass computed on per hactare basis are tabulated in Table 4. It is seen that M.azedarach recorded the maximum biomass (14947.5 kg ha^{-1}) which was 19.65 per cent and 30.05 per cent higher than L.leucocephala and E.hybrid respectively.

Total biomass showed a substantial improvement with increase in plant density. It gained significantly higher values under D_3 and D_4 compared with D_1 and D_2; D_3 and D_4 behaved statistically alike.

The interaction between species and density did not cause significant effect on total biomass computed on per hactare basis.

4.4 Plant nutrient content

4.4.1 Leaf nitrogen

The data for leaf nitrogen content demonstrated significant differences among different species (Table 5).

Table 4 Biomass ~~and its partitioning~~ production (on kg per hactare basis) in different species as influenced by various densities

Species	Plant density				
	D_1	D_2	D_3	D_4	Mean
Eucalyptus hybrid	4770	9026	12361	15666	10456
Leucaena leucaena	6442	10936	14735	15926	12010
Melia azedarch	11025	13160	17725	17880	14947
Mean	7412	11041	14940	16491	

	SE_d	C D at 5%
S	1342	2785
D	1550	3215
S x D	2685	NS

S_2 accumulated the maximum leaf nitrogen (1.74 per cent) which proved significantly higher than S_3 (1.34 per cent) as well as S_1 (1.22 per cent).

Leaf nitrogen was depressed significantly with increase in plant density. The reduction was more striking with increase in density from D_1 to D_2 than with subsequent increase in density levels.

Species x plant density interactions revealed maximum leaf nitrogen in case of S_2 D_1 while the minimum was recorded under S_1 D_4. Observing a particular density, <u>Leucaena leucocephala</u> always showed an edge over other species. It was further observed that leaf nitrogen declined in all the species with increase in plant density.

4.4.2 Leaf phosphorus

Leaf phosphorus content attained almost identical values in all the species and thus failed to reflect significant differences (Table 5). It showed however a significant reduction with subsequent increase in plant density. The species x density interaction was not found to influence the leaf phosphorus significantly. <u>Leucaena leucocephala</u> demonstrated the maximum leaf phosphorus content under all densities.

4.4.3 Leaf potassium

As evinced from Table 5, leaf potassium differed significantly under different species. Maximum leaf

Table 5 Leaf N,P,K,Ca and Mg content (%) in different species as influenced by various densities

Species	N					P					K					Ca					Mg				
	D_1	D_2	D_3	D_4	Mean	D_1	D_2	D_3	D_4	Mean	D_1	D_2	D_3	D_4	Mean	D_1	D_2	D_3	D_4	Mean	D_1	D_2	D_3	D_4	Mean
Eucalyptus hybrid	1.38	1.33	1.13	1.05	1.22	0.21	0.20	0.19	0.18	0.20	0.70	0.68	0.68	0.67	0.68	5.26	5.43	5.53	6.13	5.59	0.47	0.48	0.47	0.46	0.47
Leucaena leucocephala	1.92	1.77	1.74	1.52	1.74	0.23	0.22	0.21	0.19	0.21	1.01	0.94	0.90	0.90	0.94	5.20	5.36	5.70	5.73	5.50	0.55	0.53	0.52	0.50	0.53
Melia azedarch	1.60	1.33	1.29	1.15	1.34	0.22	0.20	0.19	0.18	0.20	0.85	0.82	0.80	0.78	0.81	4.90	5.76	5.83	6.00	5.52	0.48	0.46	0.45	0.44	0.46
Mean	1.63	1.48	1.38	1.24		0.22	0.21	0.20	0.18		0.85	0.81	0.79	0.78		5.12	5.38	5.69	5.95		0.50	0.49	0.48	0.47	

SE_d	N	P	K	Ca	Mg
S	0.40	0.008	0.02	0.20	0.02
D	0.40	0.009	0.02	0.23	0.02
S x D	0.08	0.016	0.04	0.40	0.04
C D at 5%					
S	0.08	NS	0.04	NS	0.04
D	0.09	0.02	0.04	0.48	NS
S x D	0.16	NS	0.08	NS	NS

potassium was observed in Leucaena leucocephala (0.94 per cent) followed by Melia azedarach (0.81 per cent) and Eucalyptus tereticornis (0.68 per cent).

Leaf potassium content declined with each successive increase in plant density. Significant reduction could be observed only when density increased from D_1 to D_3 or D_4. The plants under D_2, D_3 and D_4 showed no significant variation.

Leaf potassium content reflected no significant effect of species x density interaction. It registered the maximum value in Leucaena leucocephala at D_1 where as minimum was recorded for Eucalyptus hybrid at D_4. Leaf potassium content decreased in all species with subsequent increase in plant population. While observing at a particular density it varied in the order of $S_2 > S_3 > S_1$.

4.4.4 Leaf calcium

The data presented in Table 5 revealed that the calcium content could not show a significant difference in the species. Unlike leaf N and P content, it followed an increasing trend with increase in plant density. Maximum value obtained under D_4 was statistically at par with D_3 but proved significantly better than D_1 and D_2. The calcium content was not affected significantly by species x density interactions.

4.4.5 Leaf magnesium

The data presented in Table 5 shows that leaf Mg content varied significantly in different species. Leucaena leucocephala accumulated maximum leaf magnesium content which was significantly higher than other species. The Eucalyptus hybrid and Melia azedarach remained statistically at par. The density as well as species x density interactions lacked to cause significant influence on leaf magnesium content.

4.4.6 Twig nitrogen

Table 6 shows that twig nitrogen content differed significantly in different species. Eucalyptus hybrid recorded the minimum twig nitrogen which was significantly lower than other species. Leucaena leucocephala depicted slight gain over Melia azedarach; however remained statistically non-significant.

Twig nitrogen content declined significantly with increase in plant density. The reduction was more drastic from D_2 to D_3 than D_1 to D_2 or D_3 to D_4. It was further revealed species x density interaction had a significant effect on twig Nitrogen. It was observed to be maximum under S_2 D_1 (1.67 per cent) which was statistically at par with S_3 D_1 and S_3 D_2.

4.4.7 Twig phosphorus

Twig phosphorus content varied from 0.13 to 0.15 per cent among different species (Table 6). Leucaena leucocephala tons/ha   mm/ha

Table 6 Twig N,P,K,Ca and Mg content (%) in different species as influenced by various densities

Species	N					P					K				
	D_1	D_2	D_3	D_4	Mean	D_1	D_2	D_3	D_4	Mean	D_1	D_2	D_3	D_4	Mean
Eucalyptus hybrid	1.07	0.96	0.88	0.63	0.89	0.15	0.14	0.13	0.12	0.13	0.76	0.76	0.74	0.73	0.74
Leucaena leucocephala	1.67	1.15	1.00	0.78	1.15	0.18	0.16	0.15	0.14	0.15	0.86	0.81	0.80	0.78	0.81
Melia azedarch	1.55	1.49	0.79	0.64	1.12	0.16	0.15	0.14	0.13	0.14	0.72	0.69	0.67	0.65	0.68
Mean	1.43	1.20	0.89	0.68		0.16	0.15	0.14	0.13		0.78	0.75	0.73	0.72	

Species	Ca					Mg				
	D_1	D_2	D_3	D_4	Mean	D_1	D_2	D_3	D_4	Mean
Eucalyptus hybrid	4.9	5.2	5.5	5.8	5.4	0.26	0.24	0.22	0.21	0.23
Leucaena leucocephala	4.6	5.2	5.4	5.5	5.2	0.26	0.24	0.22	0.21	0.23
Melia azedarch	4.6	5.1	5.2	5.4	5.1	0.25	0.24	0.21	0.20	0.23
Mean	4.7	5.2	5.4	5.6		0.26	0.24	0.22	0.21	

SE_d	N	P	K	Ca	Mg
S	0.04	0.003	0.016	0.11	0.010
D	0.04	0.003	0.018	0.12	0.012
S x D	0.08	0.006	0.032	0.22	0.21

C D at 5%	N	P	K	Ca	Mg
S	0.09	0.01	0.03	NS	NS
D	0.11	0.01	0.04	0.30	0.02
S x D	0.18	NS	NS	0.50	NS

recorded significantly higher twig phosphorus content as compared to other species.

The increase in plant density, resulted in significant reduction in twig phosphorus content. The rate of decrease, however remained same with subsequent increase in density level.

The species x plant density interaction could not influence twig phosphorus content significantly. The maximum value was observed in case of S_2 D_1 (0.18 per cent) and minimum was obtained for S_1 D_4 (0.12 per cent). *Leucaena leucocephala* maintained more twig phosphorus at all density levels in comparison to other species.

4.4.8 Twig potassium

Twig K-content differed significantly under different species. Maximum twig potassium content occurred in *Leucaena leucocephala* (0.81 per cent) followed by *Eucalyptus hybrid* (0.75 per cent) and *Melia azedarach* (0.68 per cent).

Twig K-content declined with successive increase in plant density. Statistically significant difference, however, could be observed when density increased from D_1 to D_3 or D_4.

Twig potassium content reflected no significant effect of species x density interaction. It registered the maximum value in *Leucaena leucocephala* at D_1 whereas minimum was recorded for *Eucalyptus hybrid* at D_4. There was a general reduction in all the species with increase in plant density. While observing the variation at a particular density, species varied in order of $S_2 > S_1 > S_3$.

4.4.9 Twig calcium

Table 6 revealed that twig calcium content was not influenced significantly by the species under study. It registered the maximum value in Eucalyptus hybrid which was closely followed by Leucaena leucocephala and Melia azedarach. Twig calcium showed a positive response to plant density. Plants under D_1 contain significantly lower twig calcium then other density. D_2 and D_3 as well as D_3 and D_4 behaved statistically alike but D_2 and D_4 reflected significant differences.

Twig calcium content was found to be influenced significantly by species x plant density interaction. It increased under all the species with increase in plant density. While observing the twig calcium under particular density though no specific trend was revealed, yet Eucalyptus hybrid in general maintained its superiority.

4.4.10 Twig magnesium

Twig magnesium content showed no variation among different species. It however, declined with subsequent increase in plant density. D_1 behaved statistically alike with D_2 but proved significantly better then D_3 and D_4. The species x density interactions did not influence twig magnesium, content significantly.

4.4.11 Stem nitrogen

A perusal of Table 7 reveals that stem nitrogen content varied significantly among different species as well as densities. It recorded highest value under Leucaena leucocephala which was significantly higher than other species. The difference between Eucalyptus hybrid and Melia azedarach, however, remained statistically non-significant.

Stem nitrogen followed an inverse relation with increasing plant density. D_1 and D_2 were statistically alike, but the former attained significantly superior value over D_3 as well as D_4. Increase in plant population from D_3 to D_4 had no distant reduction in stem N.

Species x plant density did not influence stem N content significantly, though, it varied from 0.522 to 1.297 per cent. While observing stem nitrogen under particular plant density Leucaena leucocephala always showed an edge, other species.

4.4.12 Stem phosphorus

A perusal of Table 7 shows that stem phosphorus content was significantly influenced by the species under study. It attained the maximum value under L. leucocephala which was closely followed by M.azedarach and E.hybrid. There appeared to be a resiprocal relation between stem phosphorus and plant density.

Stem phosphorus did not show significant effect of species x plant density interaction. It declined under all

Table 7 Stem N,P,K,Ca and Mg content (%) in different species as influenced by various densities

Species	N					P					K					Ca					Mg				
	D_1	D_2	D_3	D_4	Mean	D_1	D_2	D_3	D_4	Mean	D_1	D_2	D_3	D_4	Mean	D_1	D_2	D_3	D_4	Mean	D_1	D_2	D_3	D_4	Mean
Eucalyptus hybrid	0.96	0.85	0.68	0.52	0.75	0.14	0.13	0.13	0.12	0.13	0.43	0.43	0.37	0.35	0.40	4.2	4.4	4.6	4.6	4.4	0.34	0.33	0.32	0.30	0.32
Leucaena leucocephala	1.30	1.23	0.81	0.71	1.01	0.18	0.15	0.14	0.14	0.15	0.58	0.57	0.56	0.50	0.55	4.2	4.4	4.5	4.6	4.4	0.41	0.39	0.38	0.35	0.38
Melia azedarach	0.91	0.82	0.72	0.67	0.78	0.15	0.14	0.14	0.14	0.14	0.49	0.47	0.46	0.40	0.46	4.2	4.4	4.5	4.5	4.4	0.27	0.25	0.23	0.21	0.24
Mean	1.06	0.97	0.74	0.63		0.15	0.14	0.14	0.13		0.50	0.49	0.46	0.42		4.2	4.4	4.5	4.6		0.34	0.32	0.32	0.28	

SE_d	N	P	K	Ca	Mg
S	0.03	0.003	0.003	0.121	0.007
D	0.04	0.004	0.004	0.139	0.008
S x D	0.07	0.007	0.007	0.242	0.014
C D at 5%					
S	0.06	0.01	0.01	NS	0.02
D	0.08	0.01	0.01	NS	0.02
S x D	NS	NS	NS	NS	NS

the species with increase in plant density. It attained maximum value under S_2 D_1 (0.18 per cent) which proved significantly higher than rest of the treatments.

4.4.13 Stem potassium

Stem K-content reflected significant differences among different species (Table 7). It assumed the maximum value in Leucaena leucocephala (0.55 per cent) followed by Melia azedarach (0.46 per cent) and Eycalyptus hybrid (0.40 per cent).

Stem K-content showed a negative relation with increase in plant population. Significant decline was observed when plant density increased from D_1 to D_3 or D_4. The plants in D_3 and D_4 however showed no significant variation.

Stem K-content reflected no significant effect of species x density interaction. It registered maximum value in S_2 D_1 whereas minimum was recorded for S_1 D_4.

4.4.14 Stem calcium

The data presented in Table depicted that the calcium content did not achieve significant differences in the species. It followed an increasing trend with increase in plant population. Maximum value obtained under D_4 was statistically at par with D_2 and D_3 but proved significantly better than D_1. The stem calcium content was not affected significantly by species x density interactions.

4.4.15 Stem magnesium

Stem magnesium content varied significantly among species (Table 8). A statistically higher value was observed in S_2 (0.38 per cent) followed by S_1 (0.32 per cent) and S_3 (0.24 per cent).

There was a pronounced decline in stem magnesium content with increase in plant density. A significant reduction was observed with increase in density from D_1 to D_2, D_3 or D_4. D_2 and D_3 were statistically at par but both proved significantly superior to D_4.

The species x density interaction did not affect stem Mg content significantly. It showed a consistent decline under all the species with increase in plant population. While observing a particular density a general trend like $S_2 > S_1 > S_3$ was revealed.

4.4.16 Root nitrogen

Root nitrogen content was significantly affected by different species as well as plant densities (Table 8). Significantly higher values was observed under Leucaena leucocephala (0.80 per cent) followed by Melia azedarach (0.74 per cent) and Eucalyptus hybrid (0.64 per cent).

There was a significant decrease in root-N with increase in density from D_1 to D_2; beyond this decrease was quite distinct but significant difference occurred only between D_3 and D_4.

Table 8 Root N,P,K,Ca and Mg content (%) in different species as influenced by various densities

Species	N					P					K					Ca					Mg				
	D_1	D_2	D_3	D_4	Mean	D_1	D_2	D_3	D_4	Mean	D_1	D_2	D_3	D_4	Mean	D_1	D_2	D_3	D_4	Mean	D_1	D_2	D_3	D_4	Mean
Eucalyptus hybrid	0.69	0.67	0.62	0.57	0.64	0.18	0.17	0.14	0.13	0.16	0.73	0.72	0.65	0.59	0.67	3.60	3.86	4.60	4.93	4.24	0.28	0.25	0.24	0.22	0.25
Leucaena leucocephala	0.96	0.82	0.70	0.63	0.80	0.16	0.14	0.13	0.12	0.14	0.76	0.72	0.68	0.62	0.70	3.66	4.26	4.56	4.90	4.42	0.25	0.24	0.21	0.20	0.23
Melia azedarach	0.85	0.75	0.71	0.66	0.74	0.19	0.16	0.15	0.14	0.16	0.81	0.76	0.74	0.67	0.75	4.30	4.77	5.03	5.40	4.85	0.27	0.25	0.22	0.21	0.24
Mean	0.83	0.75	0.70	0.62		0.17	0.15	0.14	0.13		0.76	0.73	0.69	0.62		3.85	4.77		4.73	5.07	0.27	0.25	0.22	0.21	

SE_d	N	P	K	Ca	Mg
S	0.03	0.009	0.01	0.12	0.01
D	0.03	0.010	0.01	0.14	0.01
S x D	0.05	0.20	0.02	0.24	0.02
C D at 5%					
S	0.06	NS	0.02	0.25	NS
D	0.06	0.02	0.02	0.29	0.02
S x D	NS	NS	NS	NS	NS

Species x plant density did not influence root nitrogen significantly. It attained maximum value under S_2 D_1 and minimum in S_1 D_4. Root nitrogen was reduced in all the species with increase in plant density. While observing a particular density, Leucaena leucocephala always assumed higher value in comparison to other species.

4.4.17 Root phosphorus

As is evident from Table 8 the root phosphorus content was not influenced significantly by species. S_1 and S_3 recorded identical value (0.16 per cent) which was slightly higher than S_2 (0.14 per cent).

Root phosphorus revealed an inverse trend with increase in plant density. A significant decline was observed from D_1 to D_2, D_3 or D_4. D_3 and D_4 were statistically at par but proved significantly inferior to D_1.

Root phosphorus was not found to be influenced significantly by species x density interaction. It declined under all the species with increase in plant density. Under all the densities, excepting D_2, S_3 was found to be superior over other species.

4.4.18 Root potassium

Root K-content varied from 0.67 to 0.75 per cent in different species (Table 8). Statistically superior value was obtained in Melia azedarach (0.75 per cent) which was followed by Leucaena leucocephala (0.70 per cent) and

Eucalyptus hybrid (0.67 per cent). The root K-content showed a significant reduction with increase in plant population.

The species x density interactions did not influence root- K-content significantly. However, it declined in all the species with increase in plant density. While observing a particular density, these species followed a general trend of $S_3 > S_2 > S_1$.

4.4.19 Root calcium

As seen in Table 8, root calcium content differed significantly among different species. It was found to be maximum under *M.azedarach* (4.85 per cent) followed by *L.leucocophala* (4.42 per cent) and *E.hybrid* (4.24 per cent). Root calcium showed a significant increase with corresponding increase in plant density.

The species x density interactions resulted in no significant differences in root calcium which varied from 3.60 to 5.40 per cent. A rising trend was observed in all the species with respect to density. Observing a particular density, *Melia azedarach* always maintained an edge over other species.

4.4.20 Root magnesium

The data presented in Table 8 shows that root magnesium content did not vary significantly in species.

Maximum root magnesium content was observed under E.hybrid followed by L.leucocophala and M.azedarach. Root-Mg revealed a conspicous decline with increase in plant density. D_1 though behaved statistically alike to D_2 but both the levels proved significantly better than D_3 and D_4. Species x plant density failed to cause a significant effect.

4.5 Site amelioration

4.5.1 Comparison of soil chemical properties among the experimental plots

4.5.1.1 Soil pH

Table 9 indicates that soil pH under different treatment varied only slightly i.e. 6.89 to 6.95. The species, density as well as species x density interaction did not influenced the soil pH significantly.

4.5.1.2 Organic carbon

The organic carbon content varied from 0.26 to 0.48 per cent under different species (Table 9). Maximum organic carbon content was estimated under Eucalyptus hybrid which also proved significantly higher than other species. L.leucocephala proved least effective to enhance organic carbon status.

Increasing plant density resulted in higher organic-C content. Though D_3 and D_4 were statistically alike yet both recorded significantly higher organic carbon content than D_1 and D_2. D_1 and D_2 reflected statistically similar values.

Table 10 Available Soil N,P,K content (kg/ha) under different species as influenced by various densities

Species	Available nitrogen					Available phosphorus					Available potassium				
	D_1	D_2	D_3	D_4	Mean	D_1	D_2	D_3	D_4	Mean	D_1	D_2	D_3	D_4	Mean
Eucalyptus hybrid	321.23	318.63	311.80	306.56	314.55	33.65	32.34	29.84	22.10	29.48	148.96	143.73	130.66	123.20	136.63
Leucaena leucocephala	351.06	350.30	334.73	333.36	342.36	35.52	32.50	31.65	26.21	31.47	123.20	121.33	115.73	112.00	118.06
Melia azedarch	317.46	310.03	305.53	304.93	309.48	28.76	27.68	26.98	21.06	26.11	154.93	147.46	138.13	128.80	142.33
Mean	329.91	326.32	317.35	314.95		32.64	30.84	29.39	23.12		142.36	137.50	128.17	121.30	

SE_d	N	P	K
S	2.31	0.92	2.00
D	2.67	1.07	2.31
S x D	4.62	1.85	4.00
CD at 5%			
S	4.80	1.92	4.14
D	5.54	2.22	2.79
S x D	NS	NS	NS

Organic carbon was not influenced significantly due to species x density interaction. It enhanced under all species at increasing level of density. <u>Eucalyptus hybrid</u> was found to be more efficient than others.

4.5.1.3 Available nitrogen

Available nitrogen content ranged from 309.49 to 342.36 kg ha^{-1} and was influenced significantly by different species (Table 10). The maximum value was observed under S_2 followed by S_1 and S_3.

There was consistent reduction in available N with increase in plant density. Available Nitrogen content under D_1 was statistically at par with D_2 but both of these levels proved significantly superior to D_3 and D_4. Increasing density from D_3 to D_4 did not cause significant change in available nitrogen content.

Available nitrogen was not influenced significantly by species x density interactions. It gained the maximum value under S_2 D_1 whereas minimum value occurred for S_3 D_4. In respect of different densities, <u>Leucaena leucocephala</u> established its superiority over other species. General pattern evolved was S_2 S_1 S_3. Available nitrogen declined in all the species with respect to densities.

4.5.1.4 Available phosphorus

Available phosphorus was affected significantly due to different species (Table 10). It recorded highest value

Table 9 Soil pH, Organic carbon, Exchangeable Ca and Mg as influenced by different species under various densities

Species	pH					Organic carbon (%)					Exchangeable calcium(ppm)					Exchangeable magnessium(ppm)				
	D_1	D_2	D_3	D_4	Mean	D_1	D_2	D_3	D_4	Mean	D_1	D_2	D_3	D_4	Mean	D_1	D_2	D_3	D_4	Mean
<u>Eucalyptus hybrid</u>	6.92	6.91	6.91	6.89	6.91	0.46	0.47	0.50	0.51	0.48	656	640	633	617	637	152	146	142	138	145
<u>Leucaena leucocephala</u>	6.92	6.91	6.91	6.90	6.91	0.20	0.25	0.30	0.31	0.26	633	630	623	620	627	159	150	143	142	148
<u>Melia azedarach</u>	6.95	6.95	6.94	6.94	6.94	0.37	0.37	0.39	0.43	0.39	650	633	623	603	627	143	140	135	132	138
Mean	6.93	6.92	6.92	6.91		0.34	0.36	0.39	0.41		647	634	627	613		151	145	140	137	

SE_d	pH	Orag-C	Ca	Mg
S	0.05	0.01	5.88	1.18
D	0.05	0.01	6.79	1.36
S x D	0.09	0.02	11.77	2.36
C D at 5%				
S	NS	0.02	NS	2.45
D	NS	0.03	14.10	2.82
S x D	NS	NS	NS	NS

in *Leucaena leucocephala* (31.47 kg ha^{-1}) followed by *Eucalyptus hybrid* (29.48 kg ha^{-1}) and *Melia azedarach* (26.11 kg ha^{-1}).

Plant density depicted an inverse relation with available phosphorus. D_1 behaved statistically alike to D_2 but proved significantly better than D_3 and D_4. The D_2 and D_3 did not differ significantly but the former proved statistically superior to D_4.

Interactions between species x densities resulted in no significant effect on available phosphorus. It experienced a constant decline in all the species with increasing plant population. While observing available phosphorus under particular density, a general trend of $S_2 > S_1 > S_3$ was noticed.

4.5.1.5 Available potassium

As is evident from Table 10, available K-content differed significantly under different species. It attained the maximum value under S_3 (142.33 kg ha^{-1}) followed by S_1 (136.63 kg ha^{-1}) and S_2 (118.06 kg ha^{-1}).

Significant reduction in available K was observed with increase in plant density from D_1 to D_4. The species x density interactions did not influence total available K significantly. It got more and more exhausted under all the species with increase in plant density. While comparing available K content under particular density, S_3 proved superior most followed by S_1 and S_2.

4.5.1.6 Exchangeable calcium

A perusal of Table 9 revealed that exchangeable calcium content was not influenced significantly by species. Maximum exchangeable content was estimated under S_1 (637 ppm) which was closely followed by S_3 (627 ppm) and S_2 (627 ppm).

Exchangeable calcium content was reduced with increase in plant density. Significant difference, however could only be observed between D_1 and D_3 or D_4 as well as D_2 and D_4.

Species x plant density did not influence exchangeable calcium content significantly, though it varied from 603 to 656 ppm. Under all the species exchangeable Ca was reduced with increase in plant density. Whereas under all the densities, S_1 maintained its superiority over other species.

4.5.1.7 Exchangeable magnesium

Exchangeable magnesium content varied significantly among different species (Table 9). It attained maximum value under S_2 (148ppm) followed by S_1 (145 ppm) and S_3 (138 ppm).

Exchangeable magnesium showed a pronounced reduction with increase in plant density. Significantly higher value under D_1 as compared with other densities. D_3 and D_4 behaved statistically alike but the latter obtained the minimum value.

Exchangeable Mg remained significantly unaffected due to species x density interaction. It depreciated in all the species with respect to plant density. In relation to performance of species under a particular density, S_2 proved its superiority over others.

4.5.2 Comparison of soil chemical properties between experimental plots and the blank area adjoining plantation

A comparison for seven selected chemical characteristics of soil viz. pH, organic-C, available N, P, K and exchangeable Ca and Mg was carried out between experimental plots and the blank area (Appendix-VI). It revealed that in experimental plots the pH was reduced and organic-C was enhanced under all species. The organic-C status in all experimental plots improved with increase indensity and enrichment in particular was remarkably high under <u>Eucalyptus hybrid</u>. In the remaining parameters i.e. avail N, P, K and exchangeable Ca and Mg there was appreciable enhancement at lower densities under all species. The extent of improvement, however, became less or even in certain cases experimental plots attained lower values as the density increased to D_3 or D_4. Available N, available P and exchangeable Ca under <u>Eucalyptus tereticornis</u>; available P and available K under <u>Leucaena leucocephala</u>; and available N, available P, exchangeable Ca and Mg under <u>Melia azedarach</u> were lower in experimental plots under D_4 density. The available N and exchangeable Mg under <u>Melia asedarach</u> as well as available K under <u>Leucaena leucocephala</u> were found to be lower even under D_3.

5.

D I S C U S S I O N

Increasing human population with ever - expanding expectations for material goods is causing unprecedented demands for forest products. In response to this, forest management is becoming more intensive. Efforts are being made not merely to enhance the productivity of existing stands but to raise massive forest plantations of fast growing species as well. The purpose of such plantation is to generate additional biomass and indirectly help lessen the pressure on existing stands. The culture of high density short rotation plantation, in such situations seems to offer a promising way to produce more wood biomass to meet pulp, fibre and energy requirements. Such plantations can also be exploited partially for generating substantial quantities of fodder. The productivity of the system, however, shall largely depend upon the genetic behaviour of species, plant spacings, period of rotation and species adaptability to the site. The species which fixes atmospheric nitrogen, exhibit higher solar energy conversion, and possess relatively better coppicing and nutrient utilization efficiency, shall have significant preferences in raising such plantations. The present study is a preliminary attempt to explore the growth performance and site amelioration potential of three fast growing species raised under high density plantations. This chapter provides a comprehensive explanation for the results obtained under the present investigation with the following three headings:

i) Survival, growth and biomass productivity

ii) Plant nutrient content

iii) Site amelioration

5.1 Survival, growth and biomass productivity

Survival per cent of the species varied only slightly i.e. 98.96 to 100 per cent and as such revealed no significant effect due to species, density and species x density interaction.

The plant height as well as collar diameter were influenced significantly due to species and densities; the species x density interaction, however lacked to cause any remarkable variation in these parameters. The plant height was observed to be maximum under *Leucaena leucocephala* whereas in case of collar diameter the best performance was shown by *Melia azedarach*. These results are well in confirmity with the findings of Evans and Rombold (1984) for *Leucaena leucocephala* and *Melia azedarach* as well as Sharma *et al*. (1987) for *Leucaena leucocephala* and *Eucalyptus hybrid*. The improvement in plant height and reduction in collar diameter with corresponding increase in plant density may be ascribed to the tendency of plants to grow more in height for capturing solar energy under increasing intensity of competition. These results are well in line with the findings of Chaturvedi (1983), Ven Den Driessche (1984) and Tandon *et al*. (1988).

The specific gravity showed significant effect due to species, density and species x density interaction. It attained maximum value in Leucaena leucocephala followed by Eucalyptus hybrid and Melia azedarach. The mean values of specific gravity recorded for the three species under study are in line with FRI records as well as the investigations of Shukla and Rajput (1981) in Eucalyptus hybrid and Shukla (1982) in Leucaena leucocephala. The specific gravity reflected in general, a significant reduction with increase in plant density. These results are supported with the findings of Malik (1987) who observed an appreciable reduction in specific gravity in Eucalyptus tereticornis with a subsequent increase in seedling density.

In relation to biomass per plant and its components, significant differences due to species could be observed only in case of total biomass, stem biomass and root biomass. All these three parameters showed maximum accumulation in Melia azedarach followed by Leucaena leucocephala and Eucalyptus hybrid. Leaf biomass gained its maximum value in Eucalyptus hybrid whereas twig biomass was found to be maximum in Leucaena leucocephala. Plant density showed a significant effect on total biomass per plant and its components. Values for all these parameters registered a consistent reduction with subsequent increase in plant density. Such a decline in total biomass computed on per plant basis with increase in plant density can be ascribed to an intense competition at the closer spacings. Species x density interaction resulted in significant differences only in case of stem biomass and leaf biomass. Average contribution of stem, root, leaf and twig computed on the basis of three species irrespective of density was observed to be 49.85, 22.33, 19.83 and 7.99 per cent respectively (See Table 3). Almost similar proportions were earlier observed by Gurumurthi _et al_. (1984) and Malik (1987).

Total biomass computed on per hactare basis was found to be influenced significantly only due to species and density. _Melia azedarach_ yielded the maximum biomass followed by _Leucaena leucocephala_ and _Eucalyptus hybrid_; such a trend may be attributed to variation in weight per plant alone, as the survival per cent of species showed almost identical values. The total biomass showed a significant improvement with subsequent increase in plant density. It is interesting to note that the total biomass per plant falls and total biomass per hactare rises with increase in plant density. Steinbeck (1972) in Sycamore and Zavitkovski _et al_.(1976 in Populus species reported that closer spacings generally gave the greatest MAP in the first few years. As the plantations get older and occupy the site, the yield of wider spaced plots gradually increases towards that of narrow spaced plots and sometime equals or even excels them. Similar findings indicating a direct relation between biomass per hactare and plant density are also reported by other authors (Hu _et al_.,1980; Relwani _et al_., 1980; Van Den Driessche, 1982; Malik, 1987 and Tandon _et al_., 1988). In regard to species x

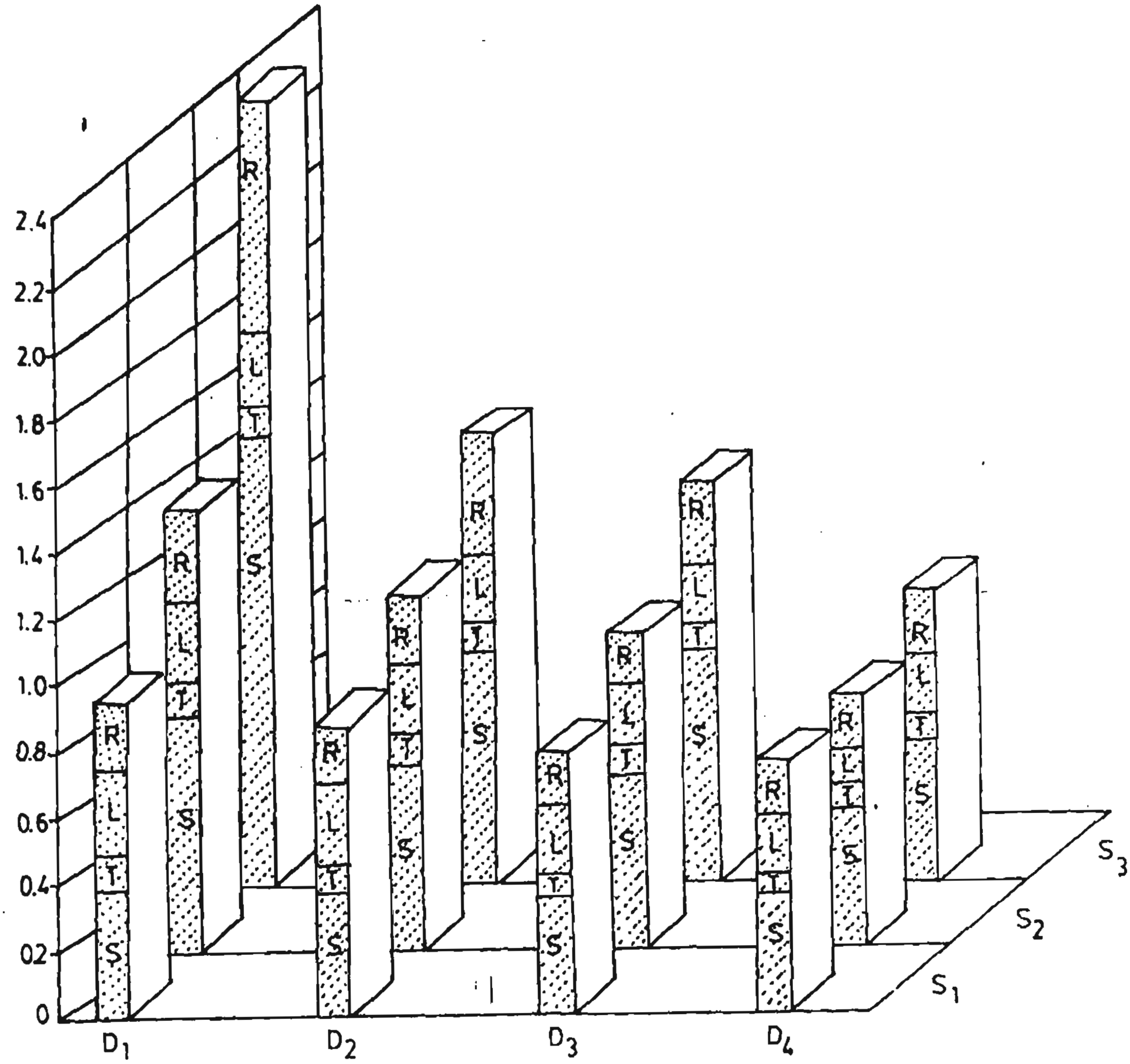

Fig. 2 : Biomass and its partitioning (on kg per plant basis).

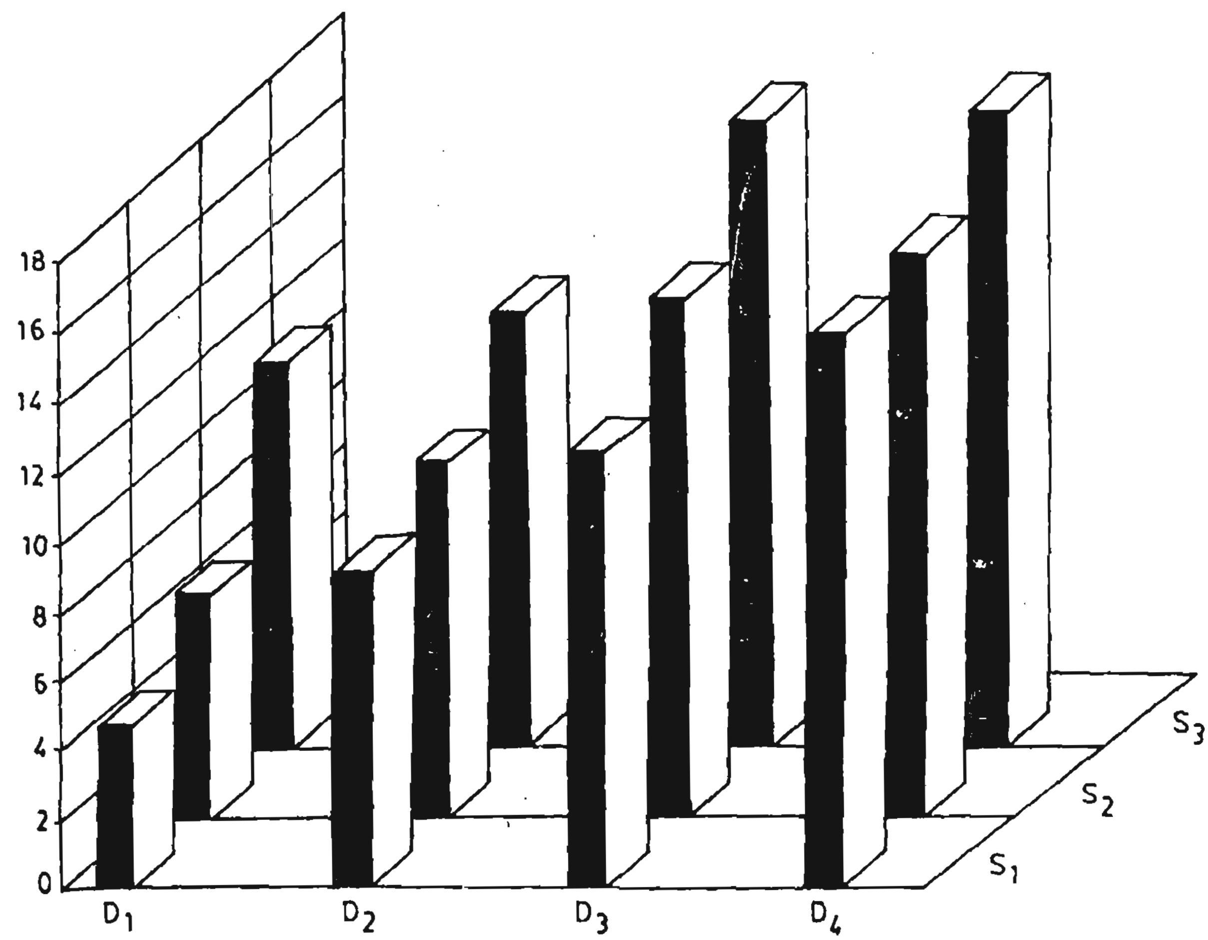

Fig. 3 : Biomass Production (tonnes per hactare).

density interaction, maximum biomass per hactare was recorded under Melia azedarach at the highest density which may be attributed to its highest weight per plant compared to other species.

5.2 Plant nutrient content

Excepting stem calcium which remained significantly uninfluenced by any of the treatments, all other characters varied significantly in either species or plant densities and many a time in both (see Table 5 to 8).

The mean values for all the nutrient elements with respect to species were highest in leaf as compared to other plant components. While comparing nutrient content in above ground components, Leucaena leucocephala emerged as the species which gathered maximum concentration of all the nutrients excepting calcium. Though Eucalyptus hybrid accumulated highest calcium in aerial components yet no significant variation among species was observed. Melia azedarach, in general, revealed comparatively higher concentration of N, P, K and lower accumulation of Ca and Mg in relation to Eucalyptus hybrid. Higher level of almost all the nutrients in Leucaena leucocephala could be attributed to close affinity of all the nutrient elements with higher levels of nitrogen in this species. George (1982), Gupta and Raturi (1984), Kaul (1988) reported similar effect in Eucalyptus tereticornis whereas Ovington and Madgwick(1959) reported it in Birch and also by Edmonds (1979) in Douglas-Fir.

Similar observations, excepting in few cases of calcium, were made by Hansen and Backer (1979) in short rotation intensively cultured plantations.

All the nutrient elements excepting calcium, in all the tree components were depressed with increase in plant density. This strengthens the earlier observations made by Gupta and Raturi (1984), Singh (1984) and Malik (1987). Calcium being an exception always followed an inverse trend to nitrogen and was enhanced with an increase in plant density. These results are in confirmity with the findings of Puri and Gupta (1954) as quoted by Raman (1984). Excessively higher concentrations of calcium in plant components may be related to its higher status in soil. Similar observations were earlier made by Wise and Pitman (1981) and Singh (1984) in *Eucalyptus hybrid*. Species x density interaction could result in significant effect in Leaf N, Leaf K, Twig N and Twig Ca.

An attempt to demonstrate the uptake of different nutrients in the species studied, revealed very interesting results. *Melia azedarach* showed the maximum uptake for all the nutrients followed by *Leucaena leucocephala* and *Eucalyptus hybrid* (Appendix-V) which is mainly a reflection of comparatively higher biomass production of the species. The effect of higher concentration of all the nutrients, in general, in different components of *Leucaena leucocephala* while computing uptake was offset by the larger variation in the biomass content of the species.

5.3 Site amelioration

Trees exert major influence on site primarily by the amount and composition of litter deposited as well as by nutrient uptake and accumulation. They also effect the amount and composition of water flow, into and through the ecosystem. Reduction in runoff and increase in infiltration under plantations also accounts for comparatively less nutrient loss as compared to soil devoid of tree growth.

Site amelioration potential of Eucalyptus hybrid, Leucaena leucocephala and Melia azedarach are reported by George (1982); Mendoza and Semana (1976); and Evans and Rambold (1984) respectively. Among the seven selected soil characteristics viz., pH, organic-C, available N, P, K and exchangeable Ca and Mg, only soil pH remained uninfluenced significantly by any of the treatments. The species x density interaction did not affect significantly any of the character. Excepting calcium, all other characteristics showed significant variation due to both species as well as densities. Higher content of organic carbon under Eucalyptus hybrid than other species, could be ascribed to as highest leaf biomass production, and slow rate of decomposition of leaves. Available N and P were found to be maximum under Leucaena leucocephala followed by Eucalyptus hybrid and Melia azedarach, whereas available K fell in the order of Melia azedarach > Leucaena leucocephala > Eucalyptus hybrid. Exchangeable calcium revealed the maximum content under Eucalyptus hybrid whereas exchangeable magnesium, was found to be highest under <u>Leucaena leucocephala</u>. The contents of all the nutrients excepting organic carbon decreased with corresponding increase in plant density indicating higher depleation of these nutrients with rising plant populations.

A comparison of soil chemical characteristics between experimental plots and the blank area adjoining to plantations revealed some interesting information. Whereas pH was reduced, the organic-C status improved under plantations. The gain in organic-C content showed a direct relation with plant density, however, it was particularly higher under <u>Eucalyptus hybrid</u>. The occurrence of relatively higher organic-C content under Eucalyptus may be attributed to slow rate of the decomposition of its foliage. The content of available N, P and K as well as exchangeable Ca and Mg reflected appreciable enhancement at lower densities under all species compared to blank area. The quantum of improvement in these parameter however,declined with increase indensity and in certain cases the values in experimental plots were lower than the blank area either at D_3 or D_4 or both. The intensive depletion of the nutrients at higher population density may have been responsible for negative values of the parameters. The available N status showed a spectacular improvement under <u>Leucaena leucocephala</u>.

S U M M A R Y

The present investigation entitled "Studies on growth performance and site amelioration under high density plantations" was carried out at Regional Research Station, Dhaulakuan, Dr.Y.S.Parmar University of Horticulture and Forestry, Solan (H.P.) during the year 1988-89. The study was carried out in energy plantation trial established during July, 1986. The experiment consisted of twelve treatment combinations comprising three species (*Eucalyptus tereticornis*, *Leucaena leucocephala*, *Melia azedarach*) and four plant densities (5,000, 10,000, 15,000, 20,000 plant per hactare). It was laid out in Factorial Randomised Block design with three raplicates. In the begining of experiment, for each species in total 960 plants were planted. The species showed a remarkable survival as only 1-2 per cent mortality could be observed during October 23-28, 1988.

Observations were recorded on survival, growth characteristics viz. plant height, collar diameter and specific gravity; total plant biomass and biomass accumulated in various plant components; N, P, K, Ca and Mg content in all plant components i.e. root, stem, twig and leaf; soil chemical properties viz. pH, organic-C, available N, P, K, exchangeable Ca and Mg. The influence of different species, various plant densities and their interactions was studied on these selected parameters.

Survival per cent was higher in Eucalyptus hybrid but it could not reveal an appreciable variation in any of the treatment. Plant height revealed a direct relation with plant density and gained significant enhancement in Leucaena leucocephala. Collar diameter was appreciably higher in Melia azedarach but was significantly reduced in all the species with increase in plant density. Leucaena leucocephala reflected highest specific gravity whereas, the minimum was observed in Melia azedarach specific gravity revealed a negative relation with plant density.

In relation to biomass per plant and its partitioning all the selected parameters namely total biomass, root biomass, stem biomass, twig biomass and leaf biomass exhibited pronounced decline with increase in plant density. As far as species effect is concerned, only first three parameters showed significant enhancement in Melia azedarach. Leaf and twig biomass could not vary significantly in species; the former was found to be highest in Eucalyptus hybrid and the latter showed highest value in Leucaena leucocephala . Total biomass per hactare was found to occur in species in the order: Melia azedarach > Leucaena leucocephala > Eucalyptus hybrid. Whereas total biomass per plant decreased, the total biomass per hactare increased with increase in plant density.

The content of N, P, K, Ca and Mg in various aerial plant components viz. stem, twig and leaf was observed to be significantly higher in Leucaena leucocephala as compared to other species. Calcium content in leaf and stem though indicated an enhancement in Eucalyptus hybrid but lack to demonstrate any significant difference among species. Also leaf phosphorus and twig magnesium revealed no significant variation among different species. The leaf reflected always the highest concentration of different nutrients i.e. N, P, K, Ca and Mg in all the species. In roots, contrasting and interesting results were observed. Appreciable variation was lacking in case of root phosphorus and root magnesium, though both the characters showed higher values in Eucalyptus hybrid . Root nitrogen, as usual was convincingly higher in Leucaena leucocephala whereas for root potassium and root calcium, Melia azedarach dominated other species. In relation to the effect of different plant densities, only leaf magnesium and stem calcium failed to reflect significant impact. Excepting calcium which was positively related with plant density, all other nutrients in all the plant components were significantly reduced with increase in plant density.

Among soil chemical properties, only one character i.e. pH, was not influenced significantly by any of the treatments. All other soil characteristics studied, excepting exchangeable calcium, showed significant variation in species. Organic-C was significantly enhanced under Eucalyptus hybrid. Available N, P and exchangeable Mg recorded appreciably higher values under Leucaena leucocephala however, available potassium attained maximum value under Melia azedarach. In response to the effect of various densities, organic carbon showed a positive relation, where as all other nutrients reflected a negative relation with increase in plant density.

A comparison of soil chemical characteristics between experimental plots and blank area adjoining the plots revealed a reduction in pH and an improvement in organic carbon status under plantations. The content of available N, P, K as well as exchangeable Ca and Mg were always found to be higher under plantations at lower densities. The values for these parameters, however, declined appreciably at higher densities and in some cases reflected lower content under plantations than blank area.

Conclusion

Total biomass production per hactare under Melia azedarach was found to be 24.45 per cent higher than Leucaena leucoephala and 42.95 per cent higher than Eucalyptus hybrid. Whereas in relation to soil improvement, Leucaena leucocephala proved to be most efficient especially with regard to available nitrogen and phosphorus status- in general the most limiting nutrient elements.

In situations, where the plantations are to be raised in degraded lands without providing any input from outside like fertilizer etc. it becomes logical to bring a compromise between biomass production and nutrient removals. Therefore from the present investigation it seems quite reasonable to conclude that Leucaena leucocephala raised at a density of 20,000 plants hactare would be a promising way for establishing such high density enery plantaions under similar site conditions.

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* Original not seen

Appendix-I

Meterological data for the experimental site during the year 1987 and 1988

Month	Temperature °C				Rainfall (mm)		Relative humidity (%)	
	1987		1988		1987	1988	1987	1988
	Min.	Max.	Min.	Max.				
Jan.	4.73	20.67	3.20	21.30	36.50	6.40	59.90	66.30
Feb.	6.88	23.11	5.10	23.90	73.40	44.50	60.05	65.55
March	10.56	27.95	8.90	26.60	30.20	67.00	52.15	56.55
April	13.23	33.73	13.60	35.50	44.80	15.00	46.45	48.50
May	17.16	32.30	19.70	36.60	233.90	44.80	50.69	44.00
June	21.40	38.10	23.00	33.20	128.00	184.90	45.30	65.00
July	24.16	34.40	24.40	29.80	255.10	823.40	69.00	86.45
August	23.16	32.00	23.90	30.30	509.70	632.50	81.45	83.20
Sep.	19.06	32.30	21.90	31.30	103.80	347.60	79.75	75.95
Oct.	12.90	30.40	12.90	29.00	35.20	-	70.75	66.80
Nov.	7.80	27.50	7.70	26.10	-	-	67.60	64.30
Dec.	4.10	22.60	5.30	20.20	6.60	146.80	67.00	65.60

Source: Meteorological observatory, Horticulture and Forestry Regional Research Station, Dhaulakuan

Appendix-II

Analysis of variance
Growth and development

Source of variance	df	Mean sum of square: Survival (%)	Plant height (m)	Collar diameter (cm)	Specific gravity
Replication	2	1.46	0.0485	0.066	0.000005
Species	2	3.30	0.8100*	1.966*	0.1207*
Density	3	1.95	0.6580*	0.945*	0.0026*
S x D	6	1.25	0.0453	0.178	0.0012
Error	22	2.63	0.0716	0.174	0.0005

Biomass and its partitioning

Source of variance	df	Mean sum of square: Total biomass (kg/plant)	Stem bio-mass (kg/plant)	Twig bio-mass (kg/plant)	Leaf bio-mass (kg/plant)	Root bio-mass (kg/plant)	Total biomass (kg/ha)
Replication	2	0.0005	0.006	0.00015	0.001	0.002	5806416
Species	2	0.0011	0.463*	0.00055	0.002	0.163*	62423125*
Density	3	0.0054*	0.285*	0.00093*	0.0086*	0.0916*	149674790*
S x D	6	0.00008	0.124*	0.00026	0.0003	0.035*	2643403
Error	22	0.0009	0.034	0.0003	0.001	0.007	10819171

*Significant at 5 per cent

Appendix-III

ANOVA

Leaf nutrient content (%)

Source of variance	df	Mean sum of square N	P	K	Ca	Mg
Raplication	2	0.0264	0.0010	0.0032	0.270	0.0005
Species	2	0.8748*	0.0012	0.1950*	0.027	0.015*
Density	3	0.1871*	0.0020*	0.0087*	1.176*	0.002
S x D	6	0.0369*	0.0006	0.0013	0.094	0.0001
Error	22	0.0087	0.0004	0.0026	0.244	0.002

Twig nutrient content

Source of variance	df	Mean sum of square N	P	K	Ca	Mg
Replication	2	0.0131	0.00001	0.0025	0.2315	0.0007
Species	2	0.2231*	0.00133*	0.0500*	0.189	0.0004
Density	3	0.9800*	0.00130*	0.0054*	1.169*	0.004*
S x D	6	0.1078*	0.00008	0.0003	0.018	0.00003
Error	22	0.0116	0.00006	0.0016	0.075	0.0007

Stem nutrient content

Source of variance	df	Mean sum of square N	P	K	Ca	Mg
Replication	2	0.0126	0.00002	0.0025	0.218	0.0002
Species	2	0.3959*	0.00138*	0.0740*	0.008	0.0625*
Density	3	0.2838*	0.00102*	0.0100*	0.283*	0.0044*
S x D	6	0.0127	0.00012	0.0003	0.006	0.0001
Error	22	0.007	0.00008	0.0010	0.088	0.0003

Contd..P-2.

Root nutrient content

Source of variance	df	Mean sum of square				
		N	P	K	Ca	Mg
Replication	2	0.013	0.0017	0.0004	0.27	0.0006
Species	2	0.075*	0.0017	0.0155*	1.175*	0.0011
Density	3	0.071*	0.0030*	0.033*	2.93*	0.0054*
S x D	6	0.006	0.0002	0.0002	0.055	0.00008
Error	22	0.004	0.0005	0.0007	0.09	0.0009

* Significant at 5 per cent

Appendix-IV

Soil nutrient content

Source of variance	df	Mean sum of square						
		pH	Organic Carbon (%)	Kg per ha			Ca ppm	Mg ppm
				N	P	K		
Replication	2	0.0005	0.0006	32.025	9.945	5.956	77.83	8.528
Species	2	0.0045	0.1562*	3759.4*	87.758*	1932.5*	344.5*	367.028*
Density	3	0.0033	0.0094*	457.68*	154.16*	797.1*	1648.18*	365.11*
S x D	6	0.0002	0.0008	26.6	3.05	43.24	137.01	11.027
Error	22	0.013	0.0008	32.11	5.16	24.01	208.07	8.37

*Significant at 5 per cent

Appendix-V

Nutrient uptake (Kg/ha) in various species as influenced by various densities

pecies	Plant Density																			
	D_1					D_2					D_3					D_4				
	N	P	K	Ca	Mg	N	P	K	Ca	Mg	N	P	K	Ca	Mg	N	P	K	Ca	Mg
TEM																				
.hybrid	18.53	7.91	2.71	81	6.56	31.41	4.81	4.81	162	12.21	36.77	7.02	7.02	248	17.28	54.22	8.64	9.36	331	21.61
.leucocephala	45.56	6.32	6.32	147	14.40	68.99	8.40	8.40	246	21.84	62.99	10.86	11.64	399	29.48	57.80	11.30	11.30	371	28.25
.azedarach	60.45	10.02	10.02	280	18.04	53.37	9.10	9.10	286	16.25	68.40	13.60	13.60	437	30.12	55.66	11.70	11.70	376	17.55
WIG																				
.hybrid	5.56	0.78	3.95	25	1.35	8.16	1.19	6.46	44	2.04	8.32	1.23	6.99	51	2.08	7.69	1.46	8.91	70	2.56
.leucocephala	8.02	0.86	4.12	22	1.25	10.58	1.47	7.45	47	2.21	13.32	2.00	10.66	71	2.93	12.90	2.32	12.90	90	3.47
.azedarch	7.21	0.74	3.63	21	1.20	13.71	1.38	6.34	46	2.21	11.30	1.78	9.28	68	2.80	3.51	10.70	2.17	90	3.34
EAF																				
.hybrid	17.73	2.71	9.01	67	6.05	33.30	5.00	17.00	135	12.00	35.53	5.99	21.42	174	14.81	37.94	6.48	24.12	220	16.56
.leucocephala	23.78	2.85	12.49	64	6.80	37.23	4.62	19.74	112	9.66	45.71	5.53	21.08	158	11.59	50.90	6.36	30.12	191	16.73
.azedarach	18.16	2.50	9.67	55	5.46	27.83	4.20	17.22	112	10.29	37.24	5.38	21.26	153	12.92	41.12	6.45	27.94	214	15.76
OOT																				
.hybrid	6.83	1.78	7.22	35	2.77	12.06	3.06	12.96	69	4.50	15.81	3.57	16.58	117	6.12	19.38	4.42	20.06	167	7.48
.leucocephala	13.30	2.22	10.53	50	3.46	18.04	3.08	15.84	93	5.28	19.16	3.23	16.92	113	5.23	13.64	2.60	13.43	127	4.33
.azedarach	29.02	6.49	27.65	131	9.22	21.50	6.72	31.92	197	10.50	26.53	5.61	27.65	187	8.22	26.26	5.67	26.66	214	8.36
OTAL																				
.hybrid	48.65	13.18	22.89	209	16.73	84.93	14.06	41.23	412	30.75	96.43	17.81	52.01	991	40.29	119.23	21.00	62.45	790	48.20
.leucocephala	90.66	12.25	33.46	284	25.91	134.84	17.57	51.43	500	38.99	141.18	21.62	60.30	692	49.23	135.24	22.58	67.75	781	52.78
.azedarach	114.84	19.75	50.97	489	33.92	126.41	21.40	64.58	643	39.25	143.47	26.37	71.79	846	54.06	126.55	34.22	34.22	896	45.01

MEAN	N	P	K	Ca	Mg
E.hybrid	87.31	16.51	44.[illegible]	501	33.99
L.leucocephala	125.48	18.51	53.24	564	41.73
M.azedarach	127.82	25.49	55.44	718	43.06

Appendix-VI

Soil chemical changes in experimental plots with respect to blank area adjoining the plantation

Species		Plant density			
		D_1	D_2	D_3	D_4
Eucalyptus hybrid	pH	6.91 (- 0.05)	6.91 (- 0.05)	6.91 (- 0.05)	6.89 (- 0.07)
	Organic-C	0.46 (+ 0.24)	0.47 (+ 0.25)	0.50 (+ 0.28)	0.51 (+ 0.29)
	N	321.23 (+14.68)	318.63 (+12.08)	311.80 (+ 5.25)	306.56 (- 0.01)
	P	33.65 (+ 6.85)	32.34 (+ 5.54)	29.84 (+ 3.04)	22.1 (- 4.7)
	K	148.96 (+29.56)	143.73 (+24.33)	130.66 (+11.26)	123.2 (+ 3.8)
	Ca	656.66 (+38.33)	640.33 (+21.00)	633.33 (+15.00)	616.66 (- 2.33)
	Mg	152.3 (+15.97)	146.3 (+ 9.97)	142.00 (+ 5.67)	137.6 (+ 1.27)
Leucaena leucocephala	pH	6.92 (- 0.04)	6.91 (- 0.05)	6.91 (- 0.05)	6.90 (- 0.06)
	Organic-C	0.20 (+ 0.02)	0.25 (+ 0.03)	0.30 (+ 0.08)	0.31 (+ 0.09)
	N	351.06 (+44.51)	350.3 (+43.75)	334.73 (+28.18)	333.36 (+26.81)
	P	35.52 (+ 8.72)	32.5 (+ 5.7)	31.65 (+ 4.85)	26.21 (- 0.59)
	K	123.2 (+ 3.8)	121.33 (+ 1.93)	115.73 (- 3.67)	112.00 (- 7.4)
	Ca	650.00 (+31.67)	633.33 (+15.00)	623.33 (+ 5.00)	620.00 (+ 1.67)
	Mg	159.33 (+23.00)	150.00 (+13.67)	142.66 (+ 6.33)	142.00 (+5 .67)

Melia azedarach	pH	6.95 (- 0.01)	6.95 (- 0.01)	6.94 (- 0.02)	6.94 (- 0.02)
	Organic- C	0.37 (+ 0.15)	0.37 (+ 0.15)	0.39 (+ 0.17)	0.43 (+ 0.21)
	N	317.46 (+10.91)	310.03 (+ 3.48)	305.53 (- 1.02)	304.93 (- 1.62)
	P	28.76 (+ 2.96)	27.68 (+ 0.08)	26.98 (+ 0.18)	21.06 (- 5.84)
	K	154.93 (+35.53)	147.46 (+28.06)	138.13 (+18.73)	128.8 (+ 9.4)
	Ca	650.00 (+31.66)	633.33 (+15.00)	623.33 (+ 5.00)	613.33 (- 5.00)
	Mg	143.33 (+ 7.00)	139.66 (+ 3.33)	135.33 (- 1.00)	132.00 (- 4.33)

Control:

pH	6.96
Organic-C	0.22
N	306.55
P	26.8
K	119.4
Ca	618.33
Mg	136.33

Values in paranthesis indicates the changes