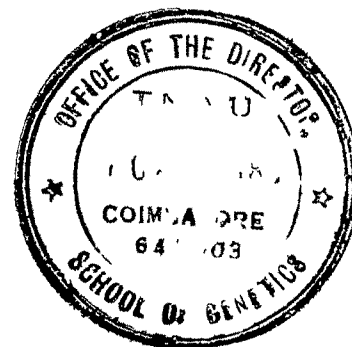
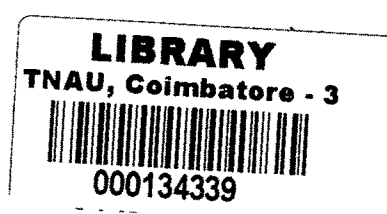


GROWTH AND BIOMASS OF *Casuarina equisetifolia* Forst.
IN DIFFERENT ECOSYSTEMS



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(I.D.Number E.B. 6)



THESIS SUBMITTED IN PART FULFILMENT OF THE REQUIREMENTS FOR
THE DEGREE OF DOCTOR OF PHILOSOPHY IN ENVIRONMENTAL BIOLOGY
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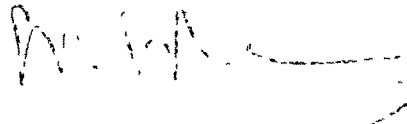
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C E R T I F I C A T E

This is to certify that the thesis entitled " GROWTH AND BIOMASS OF *Casuarina equisetifolia* Forst. IN DIFFERENT ECOSYSTEMS " submitted in part fulfilment of the requirements for the degree of DOCTOR OF PHILOSOPHY in Environmental Biology to the Tamil Nadu Agricultural University, Coimbatore is a record of **bona fide** research work carried out by **Mr.R.JAMBULINGAM** under my supervision and guidance and that no part of this thesis has been submitted for the award of any other degree, diploma, fellowship, or other similar titles or prizes and that the work has not been published in part or full in any scientific or popular journal or magazine.

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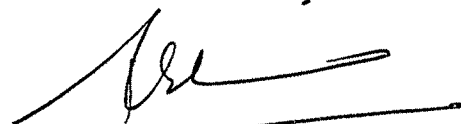

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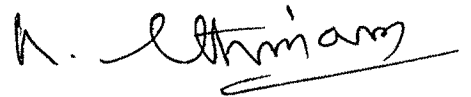
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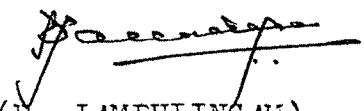
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(H. JAMBULINGAM)

ABSTRACT

ABSTRACT

GROWTH AND BIOMASS OF CASUARINA EQUISETIFOLIA Forst. IN DIFFERENT ECOSYSTEMS

By

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Casuarina equisetifolia Forst. is cultivated as a cash tree crop under the coastal, riverine and inland ecosystems. It exhibited wide variation in qualities of seed and growth characteristics. Among the seeds collected from three ecosystems, seeds from riverine ecosystem represented by Natham area along the Cauvery river banks showed maximum seed weight, germination per cent, speed of germination and better height of seedling growth, as compared to those obtained from coastal (Marakkanam) and inland (Virudhachalam) ecosystems. Seedlings from larger seeds emerged better from greater depth and the speed of germination helped

early culling out of undesirable seedlings at the nursery that are basic to improved nursery management.

Based on seed, seedling and parental characters numbering nine, a grading score was presented that would indicate seed collection areas as desirable or otherwise. Seeds obtained from trees of five or six year old trees performed better than from younger trees.

Growth studies made from seeds collected from riverine, coastal and inland areas showed that Casuarina population from riverine areas to be more stable genetically when they were studied for variation through six, nine and twelve months period. The differences between phenotypic and genotypic coefficient of variation were rather low and this would enable to exercise effective selection especially for the traits height and diameter. Cluster analysis indicated that five out of ten families from riverine area, one among coastal area and none from inland area could be considered for varietal adoption.

The open pollinated families that have been evaluated through their progeny performance indicated the possibility of using some of the elite families for developing clones or populations of superior performers.

Biomass production was influenced by site factors. The productivity of alluvial soil from riverine area was two fold over inland area. There was a progressive and consistent allocation for stem from third year to sixth year in all the areas. A concomitant decrease in allocation for branches was seen. The leaf and root contributed from 13.2 to 16.9 and 14.1 to 15.2 per cent respectively as a whole.

There was highly significant correlation between the total weight of the tree and traits like tree height, diameter at collar, stem weight, needle weight and root weight in respect of all samples. The litter-fall at six years from the riverine plantation accounted to 9.81 t/ha/year while coastal area recorded 6.06 t, the differences attributable to the total standing biomass of 169.0 and 99.7 t/ha respectively. In both the situations, needle constituted 60.6 and 50.0 per cent of the total litter-fall respectively.

The culture of Casuarina influenced the nutrient status of the plantation by allowing Casuarina to be grown that decreased the soil pH slightly while there was a progressive increase in the organic content of the soil, over a period of six years, contributed largely to slow decomposition of the needles. The available nitrogen on the surface soil increment ranged from 40.5 to 84.0 kg over a period of six years. Phosphorus and potassium contents also showed increment in soil.

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INTRODUCTION

I. INTRODUCTION

Casuarina equisetifolia Forst. was initially raised as an ornamental tree but found its way into fuelwood plantations due to its efficient burning. The earliest plantations were raised in 1860 in Karnataka (erstwhile Mysore State) followed by other states. Currently the species is widely grown along the coastal areas in almost all the states. This had well adapted to regions of sandy tracts with moderate to heavy rains (1200-2500 mm) and prefer fertile sites with high amounts of available calcium, pH values, organic matter and water table (Yadav, 1983).

The cultivation of this species in Tamil Nadu is popular along the coastal districts of Chinglepet, South Arcot, Thanjavur, Pudukottai and Ramanathapuram districts where sandy to sandy loam soils occur. It has also moved along the banks of rivers (riverine) to inland areas in the districts of Tiruchirapalli, Thanjavur and North Arcot. Its cultivation has been accepted as an alternative land use system for improving nutrient status of soil contributed by its nodules and litter-fall. The adaptation to sandy soil, resistance to saline spray and ability to grow in high density planting had proved to be successful traits for

utilization as wind breaks and shelter-belts to arrest the fury of cyclonic winds along the coasts of Orissa, Andhra Pradesh and Tamil Nadu and to control erosion by sea (Wilson 1975).

The species grown in several situations across the state showed that variation was high for stem and root weight, wood volume and total biomass. Height of tree and girth at breast height showed less variability while it was minimum for wood density in a 87 month old population (Dorairaj and Kondas 1981). In coastal ecosystem, habit wise 9.54 per cent trees showed clear stems, 75.19 per cent acute branched forms and 15.26 per cent obtuse branched stems while the per cent for the above forms were 7.97, 81.58 and 10.43 respectively for riverine stands. In inland ecosystem, the per cent ranged as 7.32, 82.95 and 9.98 for the different growth forms (Jambulingam, unpubl.).

The plantations raised in the state had emanated largely from a composite seed collection from the coastal ecosystem and to some extent from the riverine ecosystem of Thiruchirapalli district. Eventhough casuarina has been under cultivation for nearly 120 years, establishment of seed stands or genetically proven clonal orchards was not attempted so far. The seed collection was largely confined

to random trees bearing maximum cones. There was no attempt in selection of superior seedling at any stage of nursery growth.

Though several thousands of hectares of plantations have been under cultivation annually, identification of provenances either from the parent country or in its adopted countries have not been made so far. The possibility of exploiting heterozygosity resultant of largely wind pollinated species, has not been reported so far. The existence of provenances in C. equisetifolia within Australia has been reported by El-Lakany and Shepherd (1983) based on seedling characters and by Fleming et al (1988) on nodulation pattern. Quantification of plant growth based on selection of ecotypes across the regions of cultivation has not been reported so far.

Casuarina is an efficient fuelwood with a calorific value of 4127 Kcal (Rodriguez 1973). It has been found useful for paper and pulp by sulphate pulping (Guha and Madan 1963) or for chemical and semi-chemical pulping, though not suitable for mechanical pulp (Guha et al., 1970).

The State Forest Departments in the subcontinent commenced planting Casuarina at a wider espacement and longer

rotation cycle. With the success attained by the Government agencies, came the enterprising farmers of the coastal area who integrated this species into a short term rotation crop of 4 to 7 years under high density planting with more than 10,000 plants per ha under rainfed conditions. Concomitant with its growth in area, there was persistent demand for fuelwood and increasing user market pushing the market prices up.

Casuarina is one of the few multipurpose tree crops that would very well be fitting in the cropping system of rice-casuarina-rice and casuarina-groundnut-rice in the farming systems of east coast areas. Five to seven year rotation has been found to be optimum and remunerative under rainfed situation. Besides, casuarina is a soil enriching tree crop and shows profuse to moderate nodulation. It will be of significance to initiate studies to understand and to contribute to the knowledge of the seedling performance in the early phase of one year, followed by productivity in the subsequent years. Biomass productivity across locations, and in different growth stages, biomass partitioning into various plant components, more so to the tree trunk or bole need to be studied as a step towards developing managerial and breeding strategies to increase the productivity. The abundant litter-fall, the nutrient cycling and nodulation will provide

insight into soil building, besides in toto nutrient budgetting by the casuarina.

Although there are studies, in general, on various espacements and production by a few authors, a systematic and well planned study has not yet been made considering the performance of seed germination and related traits, behaviour in growth at one year, three years and six years of age of stocking. This will help in perceiving the trends in production across years and biomass accumulation and the influence on soil nutrient status under plantation conditions. The casuarina is known to exist as male and female individuals and also hermaphrodites. It is likely that considerable reservoir of genetic diversities/differentiation exists in the natural population available. Performance of seedlings derived from a single provenance across locations will provide the extent of stability in production since currently seedling of similar sources developed at a few localities alone serve as planting material. A knowledge on the net reproductive efficiency will help plan seed orchard management.

With these objectives a comprehensive study was planned to enable to understand the juvenile growth and

genotypic behaviour growth and biomass production and partitioning, and nutrients in plantation and nutrient cycling with ecological perspectives and presented and discussed in this thesis.

REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

2.1. Seed and Seedling behaviour

Bhatnagar (1966) reported that 94 per cent daylight produced most growth. Ng and Mat Asri (1979) suggested that germination of seeds of C. equisetifolia was rapid at high temperatures with 50 per cent of viable seeds germinating in 14 days. Gupta et al (1975) found that seeds should be germinated at 30°C with light for a final count on 22 days. Olsen and Pettys (1974) tested at 20°C with a 16 hour photoperiod and a final count at 34 days and found that species like C. glauca and C. cunninghamiana gave 37 per cent germination in 29 days and 35-44 per cent in 28 to 42 days respectively. Badran and El-Lakany (1978) showed that germination rate ^{6m} ~~is~~ retarded when the seeds were germinated in complete darkness. Turnbull and Martenz (1983) recommended that for C. equisetifolia var equisetifolia, 30°C temperature should be provided with the first counting on the 4th day and final count on the 22nd day. For C. equisetifolia var incana a range of temperatures such as 20; 25; 30°C ^{30°C} ~~is~~ recommended with the first count starting on the 7th day. Both the varieties needed light conditions. They had also indicated that seeds of C. equisetifolia exposed to a constant temperature at 70°C did not germinate either in full light or darkness.

8/ Halos (1983) obtained low germination for even fresh seeds. Germination per cent ranged from 1-82 per cent and averaged around 50 per cent, and was completed in 14-17 days.

Species like C. littoralis and C. stricta showed 100 per cent germination when they were sown 18 and 35 days after collection (Withers 1978).

Significant differences in germination of seeds of Casuarina cunninghamiana and C. glauca provenances were reported (El-Lakany and Shepherd 1983). In C. glauca, germination per cent correlated quadratically with the latitude of seed origin, but such relationship was not found in C. cunninghamiana. Regenerative associations in juvenile and adult stages were not uniform and tended to vary. The age of the tree, site of growth and climatic parameters had profound effect on flowering, fruiting, dispersal and germination (Kozlowski 1971). However, different opinions have been expressed for and against the influence of age on reproductive efficiency by more than one author. Generalizations were hampered by varied physiological conditions imposed by different growth rates, interaction of environment and the constraints to produce high graded seed quality unlike those in annuals and cereals where a high level

of purification has been achieved. The influence of provenance effects across gradients of fertility in their growing sites also has been profound (Baldwin 1942).

Seed production efficiency is greatest with perennial of mid age. In Pinus resinosa, seeds from mature trees with weak and open type crown produced better plants against seeds from younger actively growing individuals.

Earlier workers working on Pinus ponderosa and P. monticola felt that seeds from young trees were poor in quality while confirming that seeds from middle aged trees, when they were at the period of their "maximum volume growth", produced better seedlings (Olson 1932 and Reuss 1916). Helmer (1900), Green (1920) and Buesse (1924 and 1937). working in Pinus silvestris, Taylor (1918), and Hilf (1927) in Picea excelsa and Hofman (1921) in Psuedotsuga taxifolia also reported that seeds from young trees had higher germinative capacity than seeds from old trees.

Middle aged dominant trees had been spotted as prolific seeders while suppressed trees of the same age to produce no seed or only negligible amount (Kramer and Kozlowski 1960). Haig et al (1945) reported that cone

production continued ^{to} in increase in Pinus monticola until the trees were about 50 cm in diameter and seed production was highly correlated with tree vigour and poorly correlated with age. Agarwal (1932) was of the opinion that medium sized trees gave the best germination in Picea morinda. Kochkar (1983) described that in 27 year old P. nigra trees, seed yield was influenced by shoots of previous year. The length of catkin, seeds per cone and 1000 seed weight were also greater. Germination capacity was 24 per cent greater. Seeds exhibited better storage and the recovery of one-year old seedlings and their dimensions were better. Kozlowski (1971) showed that in uneven aged plantations characterized by continuous seed production, maximum seed production was attained in the 50 to 130 years later than in even aged stands. Gonzalez (1964) found that germination capacity and energy increased with increasing age of parent trees. Seedling vigour was not affected by the age of parent trees but seedling dry weight was significantly affected. The best age of tree from which harvest of seed to be made was considered to be 20-28 years.

Desai and Patil (1983) reported that big sized fruits of Citrus limonia contained more number of seeds and weight of seed and recorded positive relationship between

number of seeds and size of fruits. Banik (1978) studied 10,000 fruits of teak collected in Bangla Desh and graded it by weight and subdivided by size, and vice-versa. The germination tests showed size as the primary determining quality.

Sagwal (1984) reported that seed number per cone in Pinus roxburghii was variable but seed numbers were directly related to cone length and weight. Germinability was related to cone length, weight and number of seeds per cone and was less in seeds from immature cones with a high moisture content and in addition it contained light seeds. Oboho and Ali (1985) studied the effect of seed weight on early growth characters of some Savanna species like Acacia nilotica, A. albida and Azadirachta indica. They reported that germination did not vary with seed weight, but seedling height and appearance of leaflets did, being tallest for the higher weight and lowest for the low weight class.

In a provenance test of Acacia nilotica, provenance 'Fazilka' had smaller seeds (9965 per kg) that showed better germination (80.1 per cent) while 'Parakwara' provenance having larger seeds (6305 per kg) showed less germination of 75.9 per cent. Pathak et al (1980) mentioned that seedling

height of Acacia tortilis followed the pattern of seed weight whereby the tallest plants were obtained from the largest seeds. Pathak and Patil (1985) showed that the seedlings of Hardwickia binata from large seeds showed greater growth rate compared to those from smaller ones. Halos (1983) identified the size of fruits in Casuarina equisetifolia as small (< 14 mm), medium (15-20 mm) and large (> 21 mm) from one tree to the other that differed and all the number of viable seeds per fruit size showed significant difference, in germination percentages of seeds obtained from these classes of fruits. There were more viable seeds in larger fruits than in small fruits. Different select trees had yielded seeds of varying capacity. There was no correlation between diameter at breast height of select tree and germination per cent.

2.2. Family performance

El-Lakany et al (1977) studied three species of Casuarina (C. equisetifolia, C. cunninghamiana, C. glauca) and three putative hybrids of C. cunninghamiana and C. glauca through serological studies and found that C. equisetifolia was not closely related to the other two species or to the hybrids. El-Lakany and Shepherd (1983) reported significant differences in seed germination both between and within each of C. glauca and C. cunninghamiana.

In C. glauca, germination per cent correlated quadratically with the latitude of seed origin but such a relationship was not found in C. cunninghamiana. Branch length and number of cladodes (needles) per branch at 1 year varied significantly within and between species, but neither character was related to latitude of seed source. Tree height varied significantly between the provenances, with a clinal pattern of variation in C. cunninghamiana and an ecotypical one in C. glauca. Generally C. glauca grew faster than C. cunninghamiana. Basal diameter, fresh and dry weight differed within C. glauca, but not within C. cunninghamiana which had thicker diameter than C. glauca but less biomass. The levels of variation observed also suggested that useful gains might be obtained through breeding.

Fleming et al (1988) showed that plants of the group east and west of the Great Dividing Range at similar latitudes in Australia were not generally significantly different from each other in the degree of effectiveness of different host endophyt combinations under nitrogen limiting conditions. But major differences were found between northern and southern groups with regard to the host, the endophyt Frankia and their interaction, resulting in the observed variation in plant growth of Casuarina cunninghamiana.

Halos (1983) made provenance seed collection in five places in Philippines of different edapho-climatic conditions. Among the collections, seedlings from the Laquar and Pangasinan collections grew faster in height than the other provenances. Seeds from these places differed in sizes as evident from their differences in the number of seeds per gram weight.

Doralraj and Wilson (1981) showed that among fifteen Casuarina plantations studied, there were 41.7 per cent monoecious trees. The pistillate trees exceeded in growth by showing an increase of 1.42 per cent in diameter at breast height over staminate trees that was statistically non-significant. Schmidting (1983) reported that heritability increased with male flowering as it increased with age.

Wells (1986) showed that growth rate among trees within seed collection areas in Pinus taeda was quite large. Rehfeldt (1983) showed high levels of additive genetic variance within population of Douglas-fir populations. As a consequence high estimates of genetic gains in growth potential were associated with selection intensities.

Nelson and Tauer (1987) opined that the high heritability estimates for first and second year dates of

leaf fall and number of branches per decimeter in Populus deltoides were under simple genetic control. Ying and Bagley (1976) also found that phenological traits to be under strong genetic (provenance, family, clone) control. The traits that were genotypically predominant offered scope for improvement. The effectiveness of selection of any character depended not only in the availability of genetic variability in a particular environment, but also in the extent of heritability.

2.3. Biomass

Casuarina plantations were worked under the clear felling system with a rotation of thirty years in the coastal plantations of Bombay in early 1900s. Subsequently the rotation was reduced to fifteen years in 1917. But in the erstwhile Madras Presidency the rotation was reduced to seven to fifteen years. The yield then recorded was 40 tons per acre in the coastal plantations of Nellore and 28 tons in North Arcot (Troup 1921). He also suggested several espacements of 2.65x2.65, 3.0x3.0 m and 3.3x3.3 m for plantations, and 4.0x4.0 m for triangular planting.

In Tamil Nadu, C. equisetifolia was planted initially at 3.6 x 3.6 m spacing in private lands and 4.5 x 4.5 m in forest lands. This was subsequently changed

to 2.7 x 2.7 m in Mysore and 2.1 x 2.1 m in Nellore for ten years rotation while 1.8 x 1.8 m adopted for seven year rotation. Three feet (90 cm) tall, one year old seedlings were considered ideal with an average height of 2 feet (60 cm) for planting (Raghavan 1947).

Rao (1967) reported that in adopting different espacements like 1.2 x 1.2 m to 2.7 to 2.7 m the yield could be about 100-140 t/ha with a rotation of 7-10 years, along the sea coast having high humidity. Qureshi (1967) reported an average yield of $75 \text{ m}^3/\text{ha}$ (45 t/ha) at the age of five years. Venkatesan (1972) reported that yield of Casuarina varied according to the site conditions and managerial skills, eventhough he recorded 75 t/ha.

Ray (1971) indicated a spacing of 2.44 x 2.44 m (8' x 8') for West Bengal region for attaining a height of 17 m and a gbh of 35.5 cm at 8 years. Mathauda (1954) used trial plots at 1.8, 2.7 and 3.6 m square planting and opined that increased spacing from 1.8 to 2.7 m significantly reduced mortality and accelerated diameter increment. He felt that 2.7 x 2.7 m spacing to be optimum upto 7 years.

A study of several plantations of C. equisetifolia in Madras State on soil, climate and vegetation of the

various localities showed that species did best on fertile soils with high amounts of exchangeable Ca, high pH values, high organic matter and medium N content. Puri (1958) reported that it should be grown in moisture or in alternate rotations with soil improving species if it is to be planted on poor soils. This species was able to grow in competition with 'Cogon', and invading grass Imperata cylindrica, in Malaysia (Mendoza 1978).

Singh (1978) applied regression analysis to data from sample plots of C. equisetifolia near Puri with the aim of determining the optimum stocking density for the production of fuelwood. He reported wide variations in the growth performance. In West Bengal, mean annual increment (MAI) of $11.03 \text{ m}^3/\text{ha}$ (7.26 t) could be achieved with an age of 12-15 years, while in Tellore an equal MAI of $10.07 \text{ m}^3/\text{ha}$ (6.6t/ha) was obtained at age 8. Currently, yields ranging from 65 to 285 tonnes have been obtained at closer spacing. Seshadri et al (1978) recorded 250 tonnes under irrigation and fertilization at Pondicherry with a spacing of 1.0 x 1.0 m.

Singh et al (1983) studied the effect of spacing and thinning in Casuarina stands and reported that the growth was influenced by spacing as well as mortality in the early years and in subsequent years increment depended on the

cumulative volume. Thinnings did not influence growth. Maximum volume and mean annual increment (MAI) were attained at 1.83 or 2.74 m spacings in the first seven years. These spacings also produced greatest volume in all other plots over seven years old. When tree size was important, the results suggested that plantations at 1.83 m² could be thinned at seven years and harvested at 15 years without much production loss.

Verma et al (1987) reported that bole constituted the maximum biomass and it increased more than seven times from age 5 years (6.36 kg) to 15 years (46.5 kg) when the spacing was highly variable. The stocking density per hectare ranged from 739 to 1608 trees per ha for different age classes. Non-photosynthetic above ground biomass was calculated to be 2137 to 6602 kg/ha from 5 to 15 years and non-photosynthetic above ground biomass ranged from 882 kg to 1830 kgs at the end of 15 years which was quite low due to poor stocking.

Wittwer and Immel (1980) showed that growing of European alder (Alnus glutinosa) a non-leguminous nitrogen fixer in Pacific Northwest, U.S resulted in 28.5 kg of wood (per tree). This was apportioned as foliage 2.6 kg, branches 5.5 kg, bark 4.1 kg and bole 16.3 kg, all accounting

to 28.5 kg in from four year old high density planting done at a spacing of 0.9 x 0.6 m. At this spacing, the extrapolated yield was 527 tonnes/ha in 4 years, averaging 131.9 tonnes/year.

The biomass of C. equisetifolia under four espacements viz 0.3 x 0.2, 0.45 x 0.45, 0.6 x 0.6 and 1.0 x 1.0 m was assessed for its components such as by Chakrabarti (1984). He estimated 0.49, 0.73, 1.40 and 3.80 kg dry weight per plant respectively for the above espacement. He calculated 832, 432, 252 and 120 kg dry weight for the plots respectively. El-Lakany (1983) recorded 987 kg of green wood and 1470 kg of green foliage per acre at 2 years of growth when C. equisetifolia attained 204.8 cm mean height and 3.6 cm diameter under arid conditions in Egypt.

Halos (1983) reported that the rate of height and diameter growth of *Casuarina* increased with age. One year old stand showed an average height of 1.6 m, two year stand showed 2.2 m and three year old stands showed 2.5 m respectively with corresponding dbh of 0.6, 1.8, 2.6 cm.

Vivekanandan (1983) reported that in an area receiving 1250 mm annual rainfall between October to January

in Sri Lanka with porous soil and light brown fine grained sand, there was a mean annual girth increment of 3.9 to 4.4 cm only over a period of 14 years from the sixth year of plantation. Height growth in first year was 3 to 4 m. At the end of 19 years, a final yield of 449.0 m³ha (269.4 tonnes) was obtained of which the intermediate yield was 197.7 m³ha (118.6 tonnes), totalling to 388 tonnes with an average of 20.5 tonnes a year.

Pande et al (1988) showed while apportioning plant components against total weight, the per cent ranged from 49.4 to 57.5 only over a sixteen year period while bark decreased from 23.1 to 18.0 per cent. Similar fall in percentage was seen for leaf (5.4 to 1.2) and twigs (8.2 to 2.2). But branch weight increased from 13.7 to 20.1 for the same period.

The significance of forests in augmenting nutrients to the forest floor ~~was~~ influenced by the quantum of foliage and other plant parts falling on it over a period of time. The decomposition of these plant parts through the combined action of microfauna and microflora paved the way for soil enrichment. Considerable studies have been made on the mode of litter collection, quantification and nutrient

return in temperate situations both for plantation crops and native forests.

In tropical situations apart from virgin forests, monospecies plantations have been a subject of recurrent studies on the role and significance of litter in enriching the soil. Several studies undertaken in our country have focussed on Eucalyptus hybrid (George 1982), Cryptomeria japonica (Bora 1987), Pinus patula (Singh and Ramam 1979), Dalbergia sissoo (Sharma et al 1988).

Litter-fall has been used as an indication of nitrogen fixation by nodulated plants. A number of nonlegume plants often associated with forests showed an annual litter-fall in pure stands to vary from 1 to 29 t/ha/yr and a nitrogen content of 1.0 to 3.0 per cent (Silvester 1977). For a perennial plant, the nitrogen returned in litter may be a high proportion of that taken in by fixation and soil uptake. In low soil N conditions, leaf drop may^{be} used as a very rough estimate of N, but it neglects the N stored in the plant during growth and N turned over underground (Gordon and Wheeler 1983). Besides nitrogen, litter provides a multitude of nutrients like phosphorus, potassium, calcium, magnesium and ash in a comparatively less quantity. Nevertheless, the accumulation over time did confer meaningful accretion

to the soil nutrient status. In species like Acacia holosericea, litter contributed about 25 kg of N out of a net demand of 29.7 kg and 11.7 per cent of the total demand of phosphorus (Langkamp and Dalling 1982; Langkamp et al 1982). Thiyagalingam and Fahmy (1979) reported that the coffee plantations in Papua New-Guinea, the N and C content (N = 0.586%, C = 5.67%) was twice as high under casuarina as under Albizia stipulata (N = 0.25%, C = 2.95%) and Crotolaria sp (N = 0.214%, C = 2.30%). In old and young Casuarina grown in coffee plantations, old Casuarina exhibited 9.08% carbon and 0.73% nitrogen against young Casuarina registering 2.52 and 0.31 per cent carbon and nitrogen respectively.

Daniere et al (1986) studied nitrogen kinetics and seasonal litter fall in Alnus incana Forst, for three stages viz., pioneer stage, alder thicket and forest stages. Total return of combined N by annual litter fall was estimated at 72 kg/ha for the thicket stage and at 22.5 kg/ha for forest stage. Leaves of Alnus incana decomposed at a greater rate, in less than one year. Boring et al (1987) reported that Robinia psudeo-acacia exhibited litter-fall comprising leaves from over storey, under storey and related litter that contributed 86.8 kg of N against a total of 124.0 kg/ha per year. Singh and Ramam (1979) reported that litter production

in Pinus patula plantations of 10 to 25 years ranged from 3748 to 11416 kg per year per ha. This returned about 64.6 kg of silica, 61.8 kg of N, 7.05 kg of K and 3.64 kg of P. Palmer (1988) reported that dry matter production was almost proportionate to tree density. Doubling of tree density in apples from 4444 to 8888 trees per ha increased dry matter productivity by 28.0 per cent. He also attributed this increase to high interception (>80%) of photosynthetically active radiation. High dry matter produced higher litter-fall also.

2.4. Annual Nutrient Return

High density planting of Casuarina equisetifolia being common in many locations in the country, the amount of nutrients cycled solely by this species becomes important in maintaining the productivity and health of the plantation especially when no other ground flora were allowed to emerge in its shade. The litter-fall in this monocrop being almost continuous, the possibility of recouping and distributing nutrients is a major activity by the tree. Several studies have been done for temperate species in Europe and North America but practically a very few have been reported for Casuarina. The amount of nutrients available in the above ground standing biomass and that of the below ground root zone has been quantified to some extent. However a budgetting

on how much nutrient is retained and how much is released from the above ground biomass is to be understood.

Malhotra et al (1987) reported for Pinus patula that the annual return of N was 16.6, 70.0, 64.7, 89.3 and 75.4 kg/ha and return of Ca was 17.9, 64.5, 65.8, 72.8 and 79.8 kg/ha in 6, 8, 10, 12 and 14 years old plantations. Needle constituted maximum nutrients. Srivastava et al (1972) reported that leaf litter returned a substantial amount of various nutrient elements.

2.5. Net Reproductive Effort (NRE)

Net reproductive effort, otherwise parental reproductive strategy, will be a suitable starting point for assessing the seed production spectrum in tree species. This aspect is yet to receive much direct attention in a way to bring out the ecological significance. Metabolic pathways that are operative in plant energy production does bring out much variation.

Total dry matter production is the integral of crop growth rate over the entire growth period and is related to reproductive effort, the seed yield. The proportion of effort that is put into cone/seed production might vary roughly to the habitat which the tree/plant occupies. The net reproductive effort of herbaceous perennials and

perennials without vegetative reproduction for eg., trees is from 5 to 25 per cent. Harper et al (1970) have made rough estimate of net reproductive effort that ranged from specialised grain crops at 40 per cent of net annual assimilation down to 15.0 per cent by herbaceous perennials which also reproduce vegetatively.

Since photosynthesis by a single leaf is the basis for dry matter production and hence economic yield (economically useful fraction of the biological yield), the dry matter production of a single tree must correlate with the product of leaf area and photosynthetic rate. The proportion allocated in this way may be fixed and remain characteristic of a species or groups of species. It may also be plastic being subjected to environmental stress. Harper and Oden (1970) recorded a very steady seed production at between 20 and 30 per cent of total weight.

An allometric relationship may very well hold between seed yield and total dry matter production. It is possible that the seed yield increased more slowly than total dry matter. In general, increased total dry matter production resulted in increased seed yield. The biological yield refers to dry matter production and economic yield refers to

economically useful fraction of the biological yield. The partitioning of assimilates between developing parts and leaves is probably under some hormonal control. Physiological potential for making net reproductive effort seems to be due to an interplay between growth promoting and inhibiting mechanisms and particularly so in a polygamous species like Casuarina. ^{Shulc,} ~~Attempts~~ to understand the mechanism of partitioning and to find means of controlling it should receive more attention as seed production in seed orchards is a vital link in tree improvement strategies. Thus attempts to increase yield capacities (sink) and to increase photosynthetic capacities are equally important.

MATERIALS AND METHODS

III. MATERIALS AND METHODS

The establishment and growth of Casuarina in several parts of Tamil Nadu encompass different ecosystems that vary in their geographical location, edaphic feature, rainfall pattern and temperature regimes. Though quite popular in east coast sandy tracts, its spread into deeper and compact soils has been supplemented by optimum managerial skills to accelerate its productivity. While it is grown under a rainfall of more than 2000 mm in most part of the country, it is cultivated in regions of less than 1200 mm also. Under garden land conditions it is supplemented with lift irrigation.

3.1. Ecosystems

3.1.1. Coastal ecosystem

The areas coming under this extend along the coastal belts of Chingleput, South Arcot, Thanjavur and Ramnad districts. The soils are characterised by porous well drained sandy soils where sand constitutes 68-98 per cent of the soil mass. The water table lies between 3-4 m depth. The proximity of sea provides high atmospheric humidity. The soil is characterised by low organic matter, low nitrogen but high calcium. The plants require supporting irrigation in the first summer months. The pH ranges between 7.0-7.5.

3.1.2. Riverine ecosystem

This extends from the delta areas of Cauvery, Palar and Pennar river basins from the east to west upto about 100 km interior where river alluvium is deposited along the river courses. The proportion of fine sand and clay is high. Though limited by low rainfall (< 1000 mm) the soil is rich in organic matter and nitrogen. The moisture content is fair to high during summer months due to seepage of river water. The humidity is high to very high due to ever present vegetation along the cultivated fields.

3.1.3. Inland ecosystem

This is characterised by deep red lateritic soils, having a thin layer of sand. The soil becomes cloggy when moist and hardened stiff during rainless summer months. Being well drained, moisture is not retained long despite about 1200 mm of rainfall and the tree suffers growth. Water table is quite deep (10-15 m). The situation is further confounded by medium to low organic content, low phosphorus, nitrogen and slightly acidic (pH 6.5 to 7.0) soil. Humidity is very low, mostly below 60 per cent.

The areas falling under the different ecosystems are benefitted by the North-East Monsoon received between

the months of September and December. The benefit of South-West monsoon is not perceptible except for a few occasional rains during July-August along the sea coast. The rains in summer are uncertain, but occasional to the inland areas helping the species to survive the dessicating summer heat.

3.1.4. Locations

The three different ecosystems are represented by:

Marakkanam	..	Coastal
Natham	..	Riverine
Coimbatore, Virudhachalam	..	Inland

The geographical locations are noticed in Table 1, rainfall distribution in Table 2 and mean monthly temperature in Table 3.

The studies were carried out in the above centres representing Coimbatore, Thiruchirapalli and South Arcot districts. At Coimbatore, trials were restricted to pot culture studies for evaluating family performances, while in the other three centres, biomass apportioning and soil profile studies under Casuarina plantations of different ages were undertaken.

FIG.1 LOCATION OF TRIAL SITES



Table 1. Geographic location and soil characteristics of trial sites

Particulars	Coimbatore	Virudhachalam	Natham	Marakkanam
°N Latitude	11,06	11,30	10,58	12,10
°E Longitude	76,56	79,26	78,26	79,55
Max. temperature °C	35.2	38.4	38.5	40.0
Annual Rainfall mm	598.0	1259.6	672.7	1201.1
Soil type	Red loam	Red lateritic	River Alluvium	Coastal sandy
Depth	Shallow	Medium	Deep	Deep
Organic matter	Low	Low	High	Low
Calcium	Low	Low	Medium	High
Nitrogen	Low	Low	High	Low
Phosphorus	Low	Low	Low	Low

Table 2. Mean monthly rainfall in trial sites (mm)

S. No.	Month	Marakkanam ¹ (Coastal)	Natham ² (Riverine)	Virudhachalam ³ (Inland)	Coimbatore ⁴ (Inland)
1.	January	11.1	68.4	53.7	14.1
2.	February	1.2	11.6	14.6	9.2
3.	March	1.2	-	15.3	17.0
4.	April	3.5	2.4	-	50.7
5.	May	18.3	63.6	56.4	62.4
6.	June	29.3	-	43.9	42.8
7.	July	106.0	4.8	73.6	51.0
8.	August	124.4	102.8	132.5	34.5
9.	September	138.4	216.7	141.8	49.2
10.	October	281.8	83.2	215.9	146.9
11.	November	362.5	119.2	277.3	118.8
12.	December	127.4	-	134.6	41.4

1 : Average of seven years

2, 3 and 4 : Average of ten years

Table 3. Mean monthly maximum - minimum temperature in trial sites ($^{\circ}\text{C}$)

S. No.	Month	Murukkenam ¹ (Coastal)		Natham ² (Riverine)		Virudhachalam ³ (Inland)		Coimbatore ⁴ (Inland)	
		Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1.	January	28.9	19.0	29.2	21.7	29.9	20.6	29.4	17.9
2.	February	30.7	18.5	31.8	22.2	32.7	20.4	31.8	18.5
3.	March	32.5	19.8	34.9	23.4	35.9	22.4	34.5	20.5
4.	April	35.3	22.3	37.3	26.1	36.9	25.4	35.2	23.0
5.	May	38.8	23.2	38.2	27.2	38.4	26.6	34.2	23.2
6.	June	40.0	21.2	36.2	26.6	37.1	26.5	31.6	22.9
7.	July	38.3	23.6	35.8	26.3	35.0	25.1	30.3	22.2
8.	August	37.3	21.8	38.5	25.2	34.8	24.8	30.7	22.1
9.	September	36.9	21.6	35.3	25.3	34.8	24.8	31.6	21.7
10.	October	35.9	20.6	33.4	25.0	32.5	23.8	30.6	21.4
11.	November	31.3	19.3	31.8	21.4	22.7	23.5	29.6	20.2
12.	December	31.9	17.8	31.6	23.2	32.5	23.8	28.4	18.6

1 : Average of seven years

2, 3 and 4 : Average of ten years

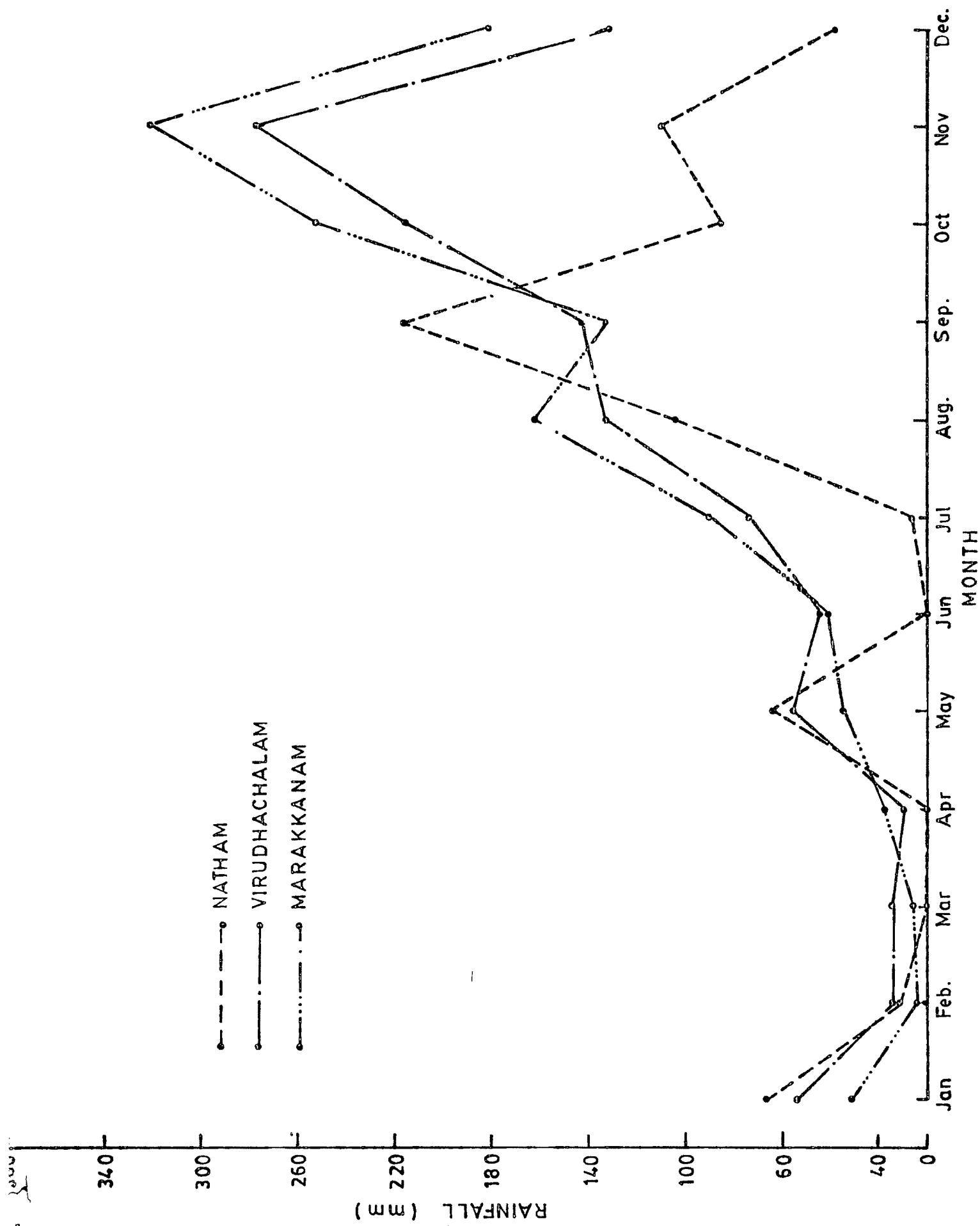


FIG. 2 MEAN MONTHLY RAINFALL IN TRIAL SITES

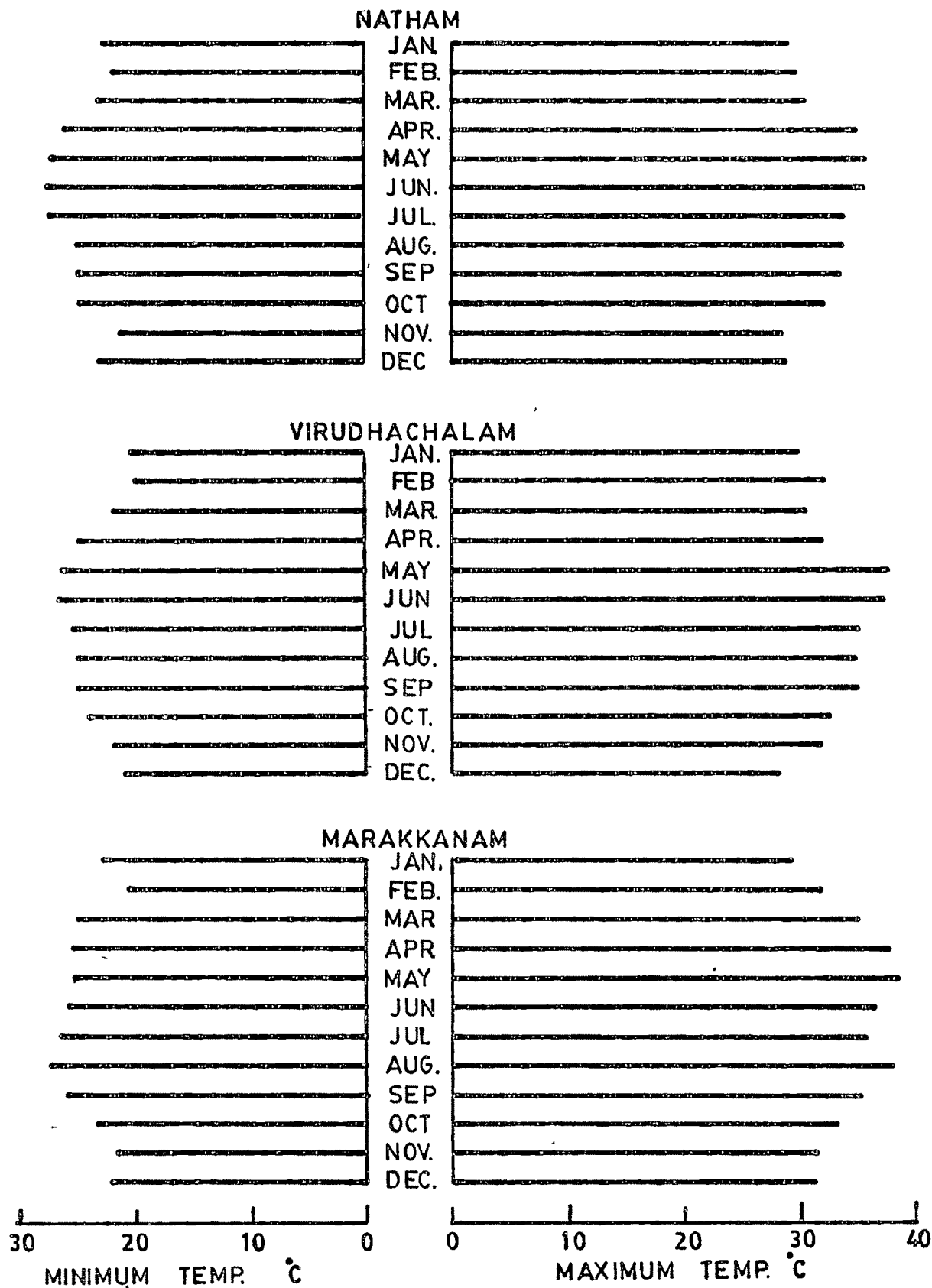


FIG. 3 MEAN MAXIMUM MINIMUM MONTHLY TEMPERATURE IN TRIAL SIT

3.2. Methods

3.2.1. Studies on germination

3.2.1.1. 100 seed weight, germination and speed of germination

Laboratory and field studies were undertaken to evaluate the performance of seeds obtained from different locations representing diverse ecosystems such as Natham, Marakkanam, Virudhachalam and Coimbatore. Cones were collected from twentyfive random trees of dominant height and diameter growth from Casuarina plantations of 5 years age. Cones were collected from the top one third of the canopy and the seeds were separated after drying in sun for three days. Seeds were collected during February-March 1981. They were tested for germination. Pooled seeds without grading were utilised for calculating hundred-seed weight. Twentyfive seeds were sown in germination papers held in glass petriplates. Radicle emergence to the length of 2 mm was considered as sign of germinability. Such of those seeds that germinated were transferred to a seedling pot containing sand:soil at 1:1 ratio and also with daily watering whenever needed. Counting of germination in the petriplates was stopped at the 20th day after distribution to petriplates.

The speed of radicle emergence was calculated according to the formula of Maguire (1962) and taken as index of the vigour of the seed source.

3.2.1.2. Optimum age of tree for seed collection

With a view to ascertain the optimum age to collect seeds or cones from trees for nursery purposes, seeds were obtained from randomly selected trees of three, four, five and six years of growth from coastal (Marakkanam), riverine (Natham) and inland (Virudhachalam) areas since the felling of the trees ranged from fourth to seventh year. The seeds were sown in galvanised germination trays of 15x15x5 cm dimension containing river sand and placed in larger trays holding water. In each tray, fifty seeds were spread with a gentle sprinkling of seed to hold the seeds. There were five replications for each tree. In all, twenty trees represented each age series and each site. The emergence of seedlings was observed for a month and the per cent germination was calculated based on the number of seeds that germinated.

3.2.2. Family testing

Thirty mother trees were selected from the undermentioned areas for studying their genetic behaviour:

<u>Areas</u>	<u>Centre</u>	<u>Number of trees</u>
1. Coastal	Marakkanam	10
2. Riverine	Natham	10
3. Inland	Virudhachalam	10

3.2.2.1. Criteria for selection of trees

In each location, trees were screened from plantations having a stocking of 75 per cent and above. Among these, the best five trees that ranked superior in height, diameter, straightness and less branching were noted. The elite among the five, based on visual estimation was selected for seed collection.

Seeds were separated out from the cone and sown in shallow 40 cm diameter seedling pans containing sand and red soil in the ratio of 2:1. Seedlings that germinated were allowed continued growth for three months when they attained about 15-20 cm growth. At this stage, they were transferred to flower pots of 40 cm diameter holding FYM: Sand:Silt at 1:1:1 ratio. For each mother tree fifteen progenies were planted out singly, to serve as five per replication (Carter 1981).

3.2.2.2. Recording of data

Height, diameter at collar and number of branches (primary and secondary) were counted and recorded for three seasons of six, nine and twelve months. Statistical design adopted was randomised block design with three replications of five plants each per source.

3.2.3. Biomass

3.2.3.1. Estimation of above ground, below ground biomass and its distribution

Estimation of above ground components like height, diameter at base, diameter at collar, shoot, twigs, branches and needle weight and reproductive parts and below ground components of roots upto 0.5 cm thickness were calculated on the basis of twenty trees felled, representing three age series of 1, 3 and 6 years in the coastal, riverine and inland areas. Soon after felling the tree, the components like stem, needle, branches and roots were separated and their dry weights recorded by drying their segments at 80°C to constant weight. The per cent contribution of each component was calculated in gms at first year and later in kg for the subsequent years, for estimation.

3.2.3.2. Litter-fall estimation

The amount of litter-fall and decomposition studies were undertaken as follows:

The litter-fall and accumulation within the plantation having three espacements (4 year age) at Marakkanam was assessed by direct method of collecting the litter in wooden trays of 50x50x8 cm dimension. The litter

accumulation in the differently spaced plantations of 1.0x1.0, 1.5x1.5 and 2.0x2.0 m was quantified for every quarter (January-March, April-June, July-September and October-December during 1981). The trays were spaced out at 50 m equidistance. Emptying was done every fortnight. The quantity of needle, cone, inflorescence and twigs were separated out at each site and calculated on a per ha basis. In all, sixty trays were displayed for litter collection. After collection, the litter was dried to constant weight and weighed to a fraction of kg. Similar studies were undertaken for IV and VI year old riverine and coastal plantations.

3.2.3.3. Estimation of nutrients

The quantity of ash, calcium, Mg, N, P and K contributed by the litter was calculated on the basis of the chemical analyses for Marakkanam for I, II, III and IV year trees and IV and VI year trees of riverine plantations.

3.2.3.4. Soil analyses

The nutrient enrichment contributed by growing casuarina in the coastal, riverine and inland areas was analysed by assessing the soil for pH, EC, Ca, Organic matter, N, P and K. Samples were drawn from soil profiles dug at

1x1x1 m dimension in the age series of 1, 2, 3, 4 and 6 years in areas of similar soil types. For each representative age series, samples from four pits were pooled and duplicate analyses made. The samples were drawn from 0-20, 20-40, 40-60, 60-80 and 80-100 cm profile range.

3.2.3.4.1. pH

Soil pH was determined in 1:2.5 soil water suspension using a pH meter (Jackson 1973).

3.2.3.4.2. EC (Electrical conductivity)

Electrical conductivity of 1:2 soil water suspension was determined with a conductivity bridge (Jackson 1973).

3.2.3.4.3. Available Nitrogen

Available Nitrogen was determined by alkaline potassium permanganate method (Subbiah and Asija 1956).

3.2.3.4.4. Available Phosphorus

Available Phosphorus in the soil was extracted with Olsens extract (0.5 N NaHCO_3) and the extracted phosphorus was determined by molybdenum blue method using

ascorbic acid as a reducing agent (Watanabe and Olsen 1965).

3.2.3.4.5. Available Potassium

Available potassium was extracted with neutral normal ammonium acetate and the potassium in the extract was determined with flame photometer (Jackson 1973).

3.2.3.4.6. Available Calcium and Magnesium

They were determined in the neutral normal ammonium acetate, by the Versenate method as described by Jackson (1973).

3.2.3.4.7. Organic carbon

This was estimated by Walkley and Black wet digestion method (Piper 1950).

3.2.3.4.8. Ash content

The estimation was done using a muffle furnace according to Jackson (1973).

3.2.4. Net Reproductive effort

Net reproduction efficiency of *Casuarina* was

estimated on calculating as per cent the amount of dry cones and seeds obtained against total dry matter of the tree (Harper and Ogden 1970).

3.2.5. Statistical procedures

The following biometrical analyses were undertaken to understand the stability of the families when grown in a common environment over a time scale of six, nine and twelve months.

3.2.5.1. Phenotypic stability analysis

The linear model proposed by Eberheart and Russel (1966) was adopted. It consisted of

$$Y_{ij} = \mu_i + b_i I_j + \quad ij + e_{ij}$$

Where,

Y_{ij} = mean performance of i^{th} single tree selection
in j^{th} growth period

μ_i = average performance of i^{th} single tree
selection over all growth periods

b_i = regression coefficient that measures the
response of the i^{th} single tree selection to
varying growth periods

i_j = the deviation from regression of the i^{th} single tree selection at j^{th} growth period

I_j = environmental index, as the deviation of the mean of all single tree selections in j^{th} growth period from grand mean, and

$$\sum_{j=1}^n I_j = 0$$

3.2.5.2. Estimation of stability parameters

The three phenotypic stability parameters viz., mean, regression coefficient 'b' and mean squared deviation ($\bar{S}_d^2$) were estimated for each single tree selection over three growth periods (Singh and Chaudhary 1984).

(a) The regression coefficient for each single tree selection was estimated as follows:

$$b_i = \frac{\sum_{j=1}^n Y_{ij} I_j}{\sum_{j=1}^n I_j^2}$$

Where,

$$\sum_j Y_{ij} I_j = \text{the sum of products of environmental index } (I_j) \text{ with the corresponding mean of that single tree selection at each growth period } (Y_{ij})$$

$$\sum I_j^2 = \text{the sum of squares of the environmental index } I_j$$

(b) The mean squared deviation from linear regression ($\bar{S}_d^2$) for each single tree selection was estimated as follows:

$$\bar{S}_d^2 = \left[\sum d_{ij}^2 / (s - 2) \right] - (0_e^{-2} / r)$$

Where,

$$\sum d_{ij}^2 = \left[\sum Y_{ij}^2 - \frac{Y_i^2}{t} \right] - \frac{\left[\sum_j Y_{ij}^2 I_j^2 \right]}{\sum I_j^2}$$

$$\sum_j d_{ij}^2 = \text{variance due to deviation from regression for a single tree selection}$$

$$\sum y_{ij}^2 - \frac{y_{i.}^2}{t} = \text{variance due to dependent variable}$$

$$\left(\sum y_{ij}^2 - I_j^2 \right) / \left(\sum I_j^2 \right) = \text{variance due to regression}$$

e^2 = mean square for pooled error

s = number of growth periods, and

r = number of replications

3.2.5.3. Estimation of variance, coefficient of variation, heritability and genetic advance

3.2.5.1. Analysis of variance

The mean values of ten plants for each type in each replication were used for the analysis of variance by the method suggested by Panse and Sukhatme (1961).

The analysis of variance table was constructed as indicated below.

Source	d.f.	M.S.	Expectation
Replication	(r-1)		
Genotypes	(t-1)	M_1	$\frac{2}{e} + r \frac{2}{g}$
Replication x Genotypes	(r-1)(t-1)	M_2	$\frac{2}{e}$

Where,

r = number of replications

t = number of genotypes

M_1 = mean square for genotypes, and

M_2 = mean square for error

The significance test was carried out by referring to the 'F' table

3.2.5.3.2. Phenotypic and genotypic variances

These were estimated according to the formula given by Johnson et al (1955).

$$\text{Genotypic variance (} \frac{2}{g} \text{)} = \frac{M_1 - M_2}{r}$$

$$\text{Phenotypic variance (} \frac{2}{p} \text{)} = \frac{2}{g} + \frac{2}{e}$$

Where,

r = number of replications, and

σ_e^2 = error variance

3.2.5.3.3. Phenotypic and genotypic coefficient of variation (PCV and GCV)

The method suggested by Burton (1952) was used

$$PCV = \frac{(\text{Phenotypic variance})^{\frac{1}{2}}}{\text{Mean}} \times 100$$

$$GCV = \frac{(\text{Genotypic variance})^{\frac{1}{2}}}{\text{Mean}} \times 100$$

3.2.5.3.4. Heritability (h^2)

Heritability in broad sense was worked out following the method given by Lush (1940)

$$h^2 \text{ (Broad sense)} = \frac{\sigma_g^2}{\sigma_p^2}$$

Where, σ_g^2 and σ_p^2 are genotypic and phenotypic variances respectively.

3.2.5.3.5. Genetic advance (GA)

Genetic advance (GA) was estimated according to the method suggested by Johnson et al (1955).

$$GA = \frac{\sigma_g^2}{p} \times K$$

Where,

σ_g^2 = genotypic variance

p = phenotypic standard deviation, and

K = selection differential (at 5% selection intensity, $K = 2.06$)

$$GA \text{ as percentage of mean} = \frac{GA}{\text{Mean}} \times 100$$

3.2.5.4. Determination of group constellation or clusters

For determining group constellations, a relatively simple criterion suggested by Tocher (quoted by Rao 1952) was followed. The criterion of grouping was that populations belonging to the same cluster should ~~atleast~~ on the average show a small D^2 than those belonging to different clusters. Starting with two closely associated types, a third variety having the smallest average D^2 for the first two was selected. Similarly the fourth one was chosen to have the smallest average D^2 from the first three and so on.

If at any stage, the average D^2 of a group appeared to be high from those already included, it was considered that the group does not fit in with the former cluster and hence, taken out side the first cluster. The groups of the first cluster were omitted and the rest treated in the same way.

After establishing the group constellations or clusters, the average inter and intra-cluster divergence was worked out taking into consideration all the component D^2 values possible among the members of the two clusters considered. The square-root of the D^2 values gave the distance (D) between the clusters.

EXPERIMENTAL RESULTS

IV. EXPERIMENTAL RESULTS

4.1. GERMINATION AND GROWTH STUDIES

Seeds of Casuarina equisetifolia were collected from select trees from plantations scattered in inland (Coimbatore, Virudhachalam), coastal (Marakkanam) and riverine (Natham) areas of South Arcot, Tiruchi and Coimbatore districts. Different aspects of germination and related characters were studied. In all twentyfive random trees were studied for each centre (Table 4).

4.1.1. Germination

4.1.1.1. Seed weight

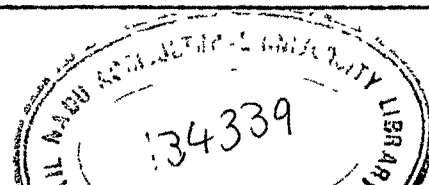
The collection from Coimbatore numbering twentyfive representing inland source showed a maximum 100-seed weight of 0.19 g and a minimum of 0.09 g. The mean was 0.12 g with a cv of 17.49. Seeds from another 'inland source' Virudhachalam showed slightly lower values with the maximum of 0.15 g and minimum of 0.07 g. However, the mean remained at 0.12 g, almost equal to the Coimbatore collection, but the cv was also 14.79 per cent. The weight of similar quantity of seeds obtained from coastal areas ranged from 0.16 to 0.09 g with a mean of 0.13 g. It showed a cv of 12.43, comparatively lower than Coimbatore and Virudhachalam samples. However, the

Table 4 . Particulars of seed, germination and tree characters

Particulars	Maxi- mum	Mini- mum	Mean	CV %
A. COASTAL				
1. <u>Marakkanam</u>				
1. 100 seed weight (g)	0.16	0.09	0.13	12.43
2. Germination (%)	62.00	13.00	37.72	35.36
3. Germination Vigour	7.68	1.74	4.76	31.72
4. Seedling height (cm)	19.58	8.05	12.25	14.12
5. Parent tree dbh (cm)	11.00	6.50	8.73	15.46
6. Parent tree height (m)	9.68	5.74	6.76	31.72
7. Cone length (cm)	2.34	1.89	2.17	6.90
8. Cone width (cm)	1.79	1.37	1.55	9.67
9. No.of ovules/cone	72.70	50.80	63.48	17.70
B. RIVERINE				
1. <u>Natham</u>				
1. 100 seed weight (g)	0.20	0.11	0.14	16.84
2. Germination (%)	72.00	12.00	41.40	39.66
3. Germination Vigour	9.54	1.74	5.37	40.22
4. Seedling height (cm)	18.56	11.18	15.28	14.13
5. Parent tree dbh (cm)	12.50	7.80	10.01	13.78
6. Parent tree height (m)	18.00	10.00	12.93	14.61
7. Cone length (cm)	2.90	2.10	2.40	9.58
8. Cone width (cm)	1.79	1.48	1.56	7.69
9. No.of ovules/cone	80.40	65.70	73.49	6.85

Table 4 . (Contd.)

Particulars	Maximum	Minimum	Mean	CV %
C. INLAND				
1. <u>Coimbatore</u>				
1. 100 seed weight (g)	0.19	0.09	0.12	17.49
2. Germination (%)	64.00	2.00	28.40	63.15
3. Germination Vigour	6.84	0.25	3.05	61.31
4. Seedling height (cm)	19.17	8.75	12.38	16.38
5. Parent tree dbh (cm)	9.20	5.40	7.27	15.22
6. Parent tree height (m)	9.60	6.00	7.84	12.24
7. Cone length (cm)	2.17	1.56	1.85	9.72
8. Cone width (cm)	1.59	1.21	1.39	7.91
9. No.of ovules/cone	66.30	36.50	50.50	29.94
2. <u>Virudhachalam</u>				
1. 100 seed weight (g)	0.15	0.07	0.12	14.79
2. Germination (%)	61.00	6.00	25.48	55.53
3. Germination Vigour	6.34	0.70	2.89	51.59
4. Seedling height (cm)	19.05	10.53	12.21	15.72
5. Parent tree dbh (cm)	9.40	6.50	7.93	10.90
6. Parent tree height (m)	10.00	6.50	7.92	10.85
7. Cone length (cm)	2.43	1.49	1.99	11.55
8. Cone width (cm)	1.79	1.33	1.45	12.41
9. No.of ovules/cone	69.50	43.70	58.72	16.84



seeds from riverine (Padugai) areas of Natham showed significantly high weight of 0.20 g for 100 seeds. The minimum weight was 0.11 g and the mean was 0.14 g. However, the cv remained at 16.84 per cent.

Coimbatore samples showed highly significant correlation with germination per cent, germination speed, seedling height, cone length and number of ovules. Positive correlation was also noticed in the samples from Virudhachalam between seed weight and all characters except non-significant positive correlation with the trait "cone length". Marakkanam seed samples showed significant positive association with all the characters. Samples from riverine areas showed the same trend, exhibiting significant positive association for six out of eight characters (Table 5).

4.1.1.2. Germination

The samples from Coimbatore exhibited wide variation ranging from 2.00 to 64.00 per cent with a mean of 28.40 and cv of 63.15, while Virudhachalam samples were slightly better regarding variation but the germination mean was only 25.48 per cent. However, Marakkanam showed a range from 13.00 to 62.00 per cent. The mean was 37.72 and the cv remained at 63.13. At Natham, the germination ranged from 12.00 to 72.00

Table 5 . Correlation values for seed weight with seed, cone and tree traits

Location	Seed weight nation %	Germi- nation vigour	Seed- ling height	Tree dbh	Tree height	Cone length	Cone width	No.of ovules
Marakkanam	0.7736**	0.7519**	0.4638*	-0.0917	-0.2555	0.5602**	0.4002*	0.4386*
		0.9650**	0.3998*	-0.0039	0.0176	0.3990*	0.3527	0.5405**
			0.3960*	0.0201	-0.5862**	0.7478**	0.2736	0.5969**
				0.1134	0.2268	0.0182	0.1502	0.4723*
					0.6937**	0.0870	0.1713	0.0672
						0.1737	0.1650	0.0102
							0.5505**	0.4338*
								0.7169**
Natham	0.8571**	0.8411**	0.7495**	-0.2619	-0.0665	0.6691**	0.3611*	0.4214*
		0.9859**	0.7323**	-0.0945	-0.0020	0.8396**	0.5987*	0.6080**
			0.4389*	-0.0816	-0.0190	0.8332**	0.5786**	0.5924**
				-0.2224	-0.1669	0.3848*	0.3987*	0.0281
					-0.5302	0.4269*	0.2180	0.0763
						0.2410	0.0836	0.0233
							0.7013**	0.7207**
								0.8642**

Table 5. (Contd.)

Location	Seed weight	Germi- nation %	Germi- nation vigour	Seed- ling height	Tree dbh	Tree height	Cone length	Cone width	No.of ovules
Coimbatore		0.7014**	0.7367**	0.8986**	-0.1395	0.0846	0.5637**	0.3445	0.5140**
			0.9946**	0.5434**	0.0740	-0.1839	0.8209**	0.4778*	0.7486**
			0.4840*		0.0659	-0.1576	0.8452**	0.4944*	0.7726**
					-0.1287	0.3333	0.3816	0.0310	0.3964*
						0.7650**	0.2302	0.0218	0.0763
Virudhachalam							-0.1974	-0.1633	-0.3585*
								0.5919**	0.9014**
									0.5669**
		0.7290**	0.6997**	0.4926*	-0.2324	-0.3225	0.3023	0.2474	0.4311*
			0.9658**	0.4750*	-0.5575**	-0.1212	0.0540	0.0630	0.4901*
				0.5720**	-0.0180	-0.1565	0.3355	0.0286	0.6951**
					0.3711	0.0611	0.6197**	0.4936*	0.4568*
						0.4180*	0.2008	0.0572	0.4639*
							0.3688	0.1301	0.5440**
								0.5137**	0.5354**
									0.8514**

per cent averaging 41.40 with a cv of 39.66. These two centres showed comparatively lower variation than Coimbatore and Virudhachalam (Fig. 4).

Germination per cent showed highly significant positive correlation with germination vigour, seedling height and number of ovules per cone and significant correlation with cone-width. Similar positive association was seen with the same trait in Virudhachalam samples. However, there was a negative significant association with tree diameter at breast height (dbh) and non-significant negative correlation with tree height. Yet, number of ovules per cone was positively associated with germination vigour. Similar trend was noticed in the case of samples from Marakkanam and Natham areas. In all the cases there was a negative association with the tree dbh and tree height.

4.1.1.3. Speed of germination

Among the two locations for inland collections, samples from Coimbatore showed a slightly higher mean value of 3.05 against 2.89 of Virudhachalam sample. In both the cases, the maxima were 6.84 and 6.34 and minima were 0.25 and 0.70 respectively. There was a high cv of 61.31 for Coimbatore samples but Virudhachalam sources showed only 51.59. When compared between the coastal and riverine(Padugai)

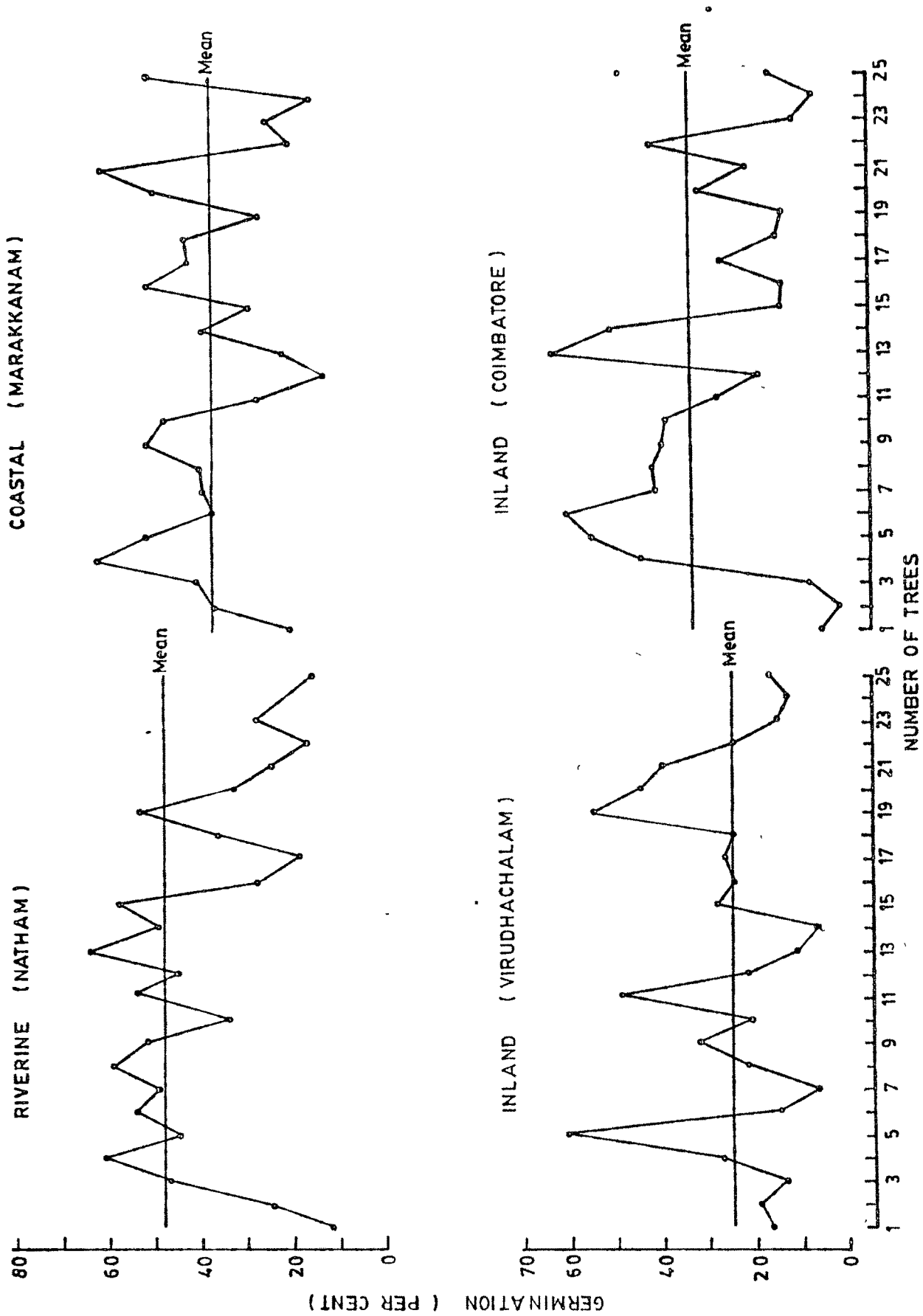


FIG. 4 GERMINATION PER CENT OF SEEDS FROM DIFFERENT AREAS

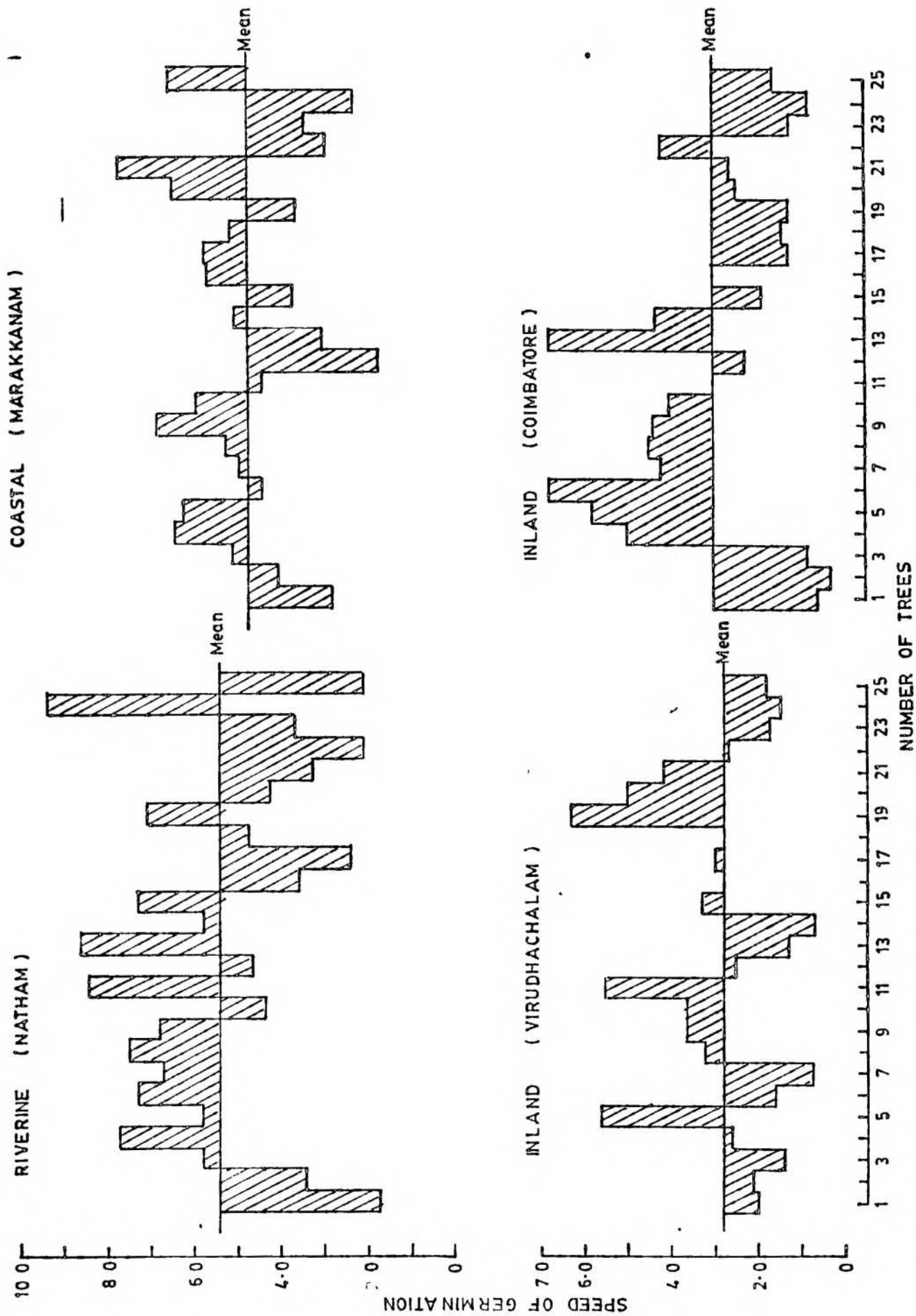


FIG.5 SPEED OF GERMINATION IN SEEDS FROM DIFFERENT AREAS

samples, coastal sample showed a maximum of 7.68 and a minimum 1.74 while the riverine was 9.54 and 1.74. The mean for the two centres were 4.76 and 5.37 respectively, the higher value moving to riverine source. Marakkanam showed a slightly lesser cv of 31.72 while Natham showed 40.22, despite the high performance of the latter (Fig. 5).

Correlation of speed of germination was significantly positive with seedling height, cone width, length and number of ovules in the case of seeds from Coimbatore. In Virudhachalam seed source, there was a positive correlation with all the above characters but statistical significance could be had for seedling height and number of ovules per cone. Marakkanam samples followed the same trend except the negative correlation with tree height and tree dbh that was highly significant. The riverine sample followed the pattern of inland sources wherein positive correlation was seen for seedling height, cone length, cone width and number of ovules per cone.

4.1.2. Seedling and parent performance

4.1.2.1. Seedling height

The emergence and growth of seedlings indicated the desirability of a good seed source. The seedlings from Coimbatore showed a mean height growth of 12.38 cm with a cv of

16.38. The Virudhachalam sample showed almost identical height growth (12.21 cm) against a cv of 15.72, nearer to that of Coimbatore source. Marakkanam seed sources showed similar mean growth (12.25 cm) but their maximum extended to 19.58 cm and minimum to 8.05 with a cv of 14.12. Natham seeds showed superior growth recording a mean height of 15.28 cm for almost identical cv of 14.13.

Seedling height showed positive correlation with tree height and cone length; non-significant correlation with tree dbh but significant correlation with number of ovules per cone for Coimbatore source. With regard to Virudhachalam source, seedling height was significantly correlated with cone length, cone width and number of ovules per cone. The positive correlation with tree 'dbh' did not attain statistical significance. Marakkanam samples showed positive significant correlation with the number of ovules per cone but not significant correlation with other traits. On the contrary, riverine samples showed significant positive correlation with cone length, cone width and no correlation with the number of ovules per cone.

4.1.2.2. Parent tree dbh

The dbh (diameter at breast height) is an important source of measurement in forestry parley to quantify biomass

and vigour of the standing stock. In this case, the dbh of the tree is taken as a measure to group the parent. Dbh was high at 9.2 cm and low at 5.4 cm for Coimbatore sample with a mean of 7.27 and a cv of 15.22. Virudhachalam samples showed almost identical growth with a maximum of 9.4 cm and a minimum of 6.5 cm while the mean was 7.93 cm and the cv 10.9. The parent trees at Marakkanam showed slightly better growth with dbh reaching a maximum of 11.0 cm and minimum 6.5 cm with the mean of 8.73 cm. The cv was 15.46. In the case of riverine seed sources, parent tree dbh ranged from 7.8 to 12.5 cm with an average of 10.0 cm as exemplified by better growing conditions. The cv was also low at 13.78 as against 15.46 of coastal samples.

The dbh was positively correlated with tree height and number of ovules per cone for Virudhachalam sample. For Marakkanam, Coimbatore and Natham samples, the correlation was found significant with tree height only. The other traits like cone width and number of ovules per cone did not show any positive correlation.

4.1.2.3. Parent tree height

Coimbatore seed source parents sported 7.84 m mean height with a cv of 12.24 while Virudhachalam sources showed almost similar height growth of 7.93 m with a cv of 10.90.

The parent tree height ranged from 5.74 to 9.68 m averaging 6.76 m with a high cv of 31.72 at Marakkanam. The trees from riverine areas showed a maximum of 18.0 m and a minimum of 10.0 m averaging to 12.93 m. The cv was very low at 14.61.

Tree height showed negative but non-significant correlation with cone length, cone width and number of ovules per cone in the Coimbatore source. But, the sample at Virudhachalam showed positive significant correlation with the number of ovules only. Non significant positive correlation was obtained for two traits in respect of coastal and riverine seed sources.

4.1.2.4. Cone length

It showed a maximum length of 2.17 cm, minimum of 1.56 and a mean of 1.85 with a cv of 9.72 for Coimbatore sample. Virudhachalam sample showed slightly longer cones. The length extended to a maximum of 2.43, minimum of 1.49 and a mean of 1.99. The cv was 11.55 only. The Marakkanam seed sources showed maximum length of 2.34 cm, a minimum of 1.89 and a mean of 2.17 with a cv of 6.9 only. The riverine samples were long with a mean of 2.40 cm with the maximum and minimum of 2.9 and 2.1 cm. The coefficient of variability was slightly high (9.5) as compared to the others. The cone length has a positive

significant correlation with cone width and number of ovules in all the situations uniformly; in most cases attaining highly significance level.

4.1.2.5. Cone width

It has a width of 1.59 to 1.21 cm averaging 1.39 cm for Coimbatore sources. Similarly, Virudhachalam samples showed a maximum width of 1.79 cm and a minimum width of 1.33 with a mean of 1.45 cm. The cv recorded in both the cases were 7.91 and 12.41 respectively. Marakkanam samples showed maximum cone width of 1.79 cm and a minimum of 1.37 cm with an average of 1.55 cm and a cv of 9.67. On the contrary, riverine seed source had a cone width of 1.79 cm and a minimum of 1.48 cm, but with an average of 1.56 cm, the cv recorded was 7.69.

Correlation-wise, the cone width was strongly correlated with the number of ovules per cone uniformly in most cases. The Virudhachalam, Marakkanam and Natham samples showed significant positive trend.

4.1.2.6. Number of ovules per cone

In the inland sources, the number of ovules per cone varied from 36.50 to 66.30 (Coimbatore) and 43.7 to 69.50 (Virudhachalam). The means were 50.50 and 58.72 for

both the centres respectively. The variation was high at Coimbatore (cv 29.94) than at Virudhachalam (cv 16.84). In the coastal area, represented by Marakkanam, the number ranged from 50.8 to 72.70 with a mean of 63.48 (cv 17.70) showing superiority over the two inland samples. The variability was also low. But, the collections from the riverine area showed higher number as indicated by the range of 65.70 to 80.40 averaging at 73.49 with least variability (cv 6.85).

Number of ovules per cone had shown positive and significant correlation with seed weight, germination per cent, germination speed, seedling height, cone length and cone width, in all the centres. Barring the Virudhachalam collections, the rest showed either poor or negative correlation with tree height and diameter at breast height.

4.1.3. Influence of age of parent tree on seed germination

Tree aged 3, 4, 5 and 6 years were selected for the study and their seeds used for testing germination efficiency. These trees represented the three habitats of inland, coastal and riverine areas (Table 6).

4.1.3.1. Inland samples (Virudhachalam)

Among the four age groups selected, seeds from the

Table 6. Influence of tree age on seed germination

Location	Particulars	Year			
		III	IV	V	VI
A. COASTAL					
	Maximum	41.16	44.23	46.53	46.91
	Minimum	14.53	20.98	19.92	19.87
	Mean	28.89	34.12	35.06	35.05
	CD			0.66	
B. RIVERINE					
	Maximum	34.82	40.97	47.10	46.15
	Minimum	19.03	20.23	23.83	23.82
	Mean	27.56	32.55	36.58	36.96
	CD			0.65	
C. INLAND					
	Maximum	35.42	38.44	41.16	43.27
	Minimum	17.08	17.39	16.82	19.03
	Mean	26.71	30.35	32.76	32.62
	CD			0.81	

6 yr old trees showed maximum germination of 43.27 per cent followed by 41.16 (5th year), 38.44 (4th year) and 35.42 (3rd year). Even the minimum germination per cent was also highest in the 6th year plantation. When the mean was considered, 5th year was slightly superior to 6th year but statistically both were on par (Table 6).

4.1.3.2. Coastal samples (Marakkanam)

In this case also, maximum germination was obtained from 6 and 5 year old trees. The mean germination per cent was, however, same for both these age groups.

4.1.3.3. Riverine sample (Natham)

Seeds collected from different age groups indicated a range from 34.82 to 47.10 per cent. But, the mean germination was highest at 5 and 6 years and both were on par statistically. The youngest age of 3 years showed a mean minimum of 27.56 per cent.

4.2. FAMILY PERFORMANCE

The seedlings of C. equisetifolia now available for planting are from composite sources of mixed origin drawn from a number of trees from several sites. This has led to the production of seedlings having different rates of growth in

respect of height, diameter and maturity. Plantations that were stocked with these seedlings showed variation in survival, height, diameter of stem and ~~in~~ stature. Hence, there is a growing need to obtain planting materials endowed with faster growth rate and minimum variability.

In this study open pollinated seeds were collected from three areas in Tamil Nadu from tree stocks which were phenotypically superior. Seeds were collected from ten trees from each area and their seedling characteristics studied under uniform conditions for a period of one year. The observations were recorded at six, nine and twelve months of age of seedlings.

4.2.1. Growth over age

4.2.1.1. Plant height

4.2.1.1.1. 6 months stage

The coastal families showed an overall mean height of 57.7 cm with a range of 45.8 to 85.13 cm with the maximum attained by family 6. Among the riverine families, average height of the families was at 76.80 cm. The lowest height was exhibited by family 20, recording 63.00 cm while the maximum of 88.93 cm was recorded by family 16. Families of inland sources showed a lesser growth than riverine source; their

average height was 54.90 cm with a range of 41.00 to 70.53 cm. The statistical analyses for the above families showed significant differences between the locations and within the location among different families (Table 7; Fig.6; Appendix I).

4.2.1.1.2. 9 months stage

The observations showed almost a parallel trend as recorded at 6 months age. The coastal families showed a mean of 81.71 cm with a range of 65.95 to 116.47 cm, the highest maintained by family 6. Among the families of riverine areas, the average height was 98.84 cm. The minimum and maximum height recorded were 85.10 and 109.80 cm respectively. The inland families showed comparatively slower growth where the average value was 75.36 cm. The minimum growth was also low (56.26 cm) and the maximum was only 98.00 cm exhibited by family 27. The differences between the families and within the families were statistically significant (Table 8; Fig.7; Appendix II).

4.2.1.1.3. 12 months stage

The coastal families progressed to reach a mean height of 104.5 cm with a range of 87.8 to 138.5 cm while the riverine families showed much faster growth. They averaged 131.6 cm. The maximum of 149.1 cm was maintained by family

Table 7. Growth of Casuarina at coastal, riverine and inland families -
Height at 6 months

Family	Coastal	Family	Riverine	Family	Inland	Mean
1	55.93	11	70.46	21	45.02	57.20
2	51.73	12	84.53	22	53.06	63.11
3	47.93	13	77.40	23	46.06	57.31
4	57.53	14	73.33	24	64.93	66.60
5	45.80	15	80.93	25	57.33	61.30
6	85.13	16	88.93	26	57.93	77.35
7	58.73	17	71.53	27	70.53	66.93
8	57.66	18	73.60	28	52.40	61.22
9	51.93	19	80.33	29	60.80	64.35
10	64.60	20	63.00	30	41.00	56.20
Mean	57.70		76.80		54.90	

	SED	CD 5%
Family	2.79	5.60
Source	1.52	3.06
Family x Source	4.84	9.70

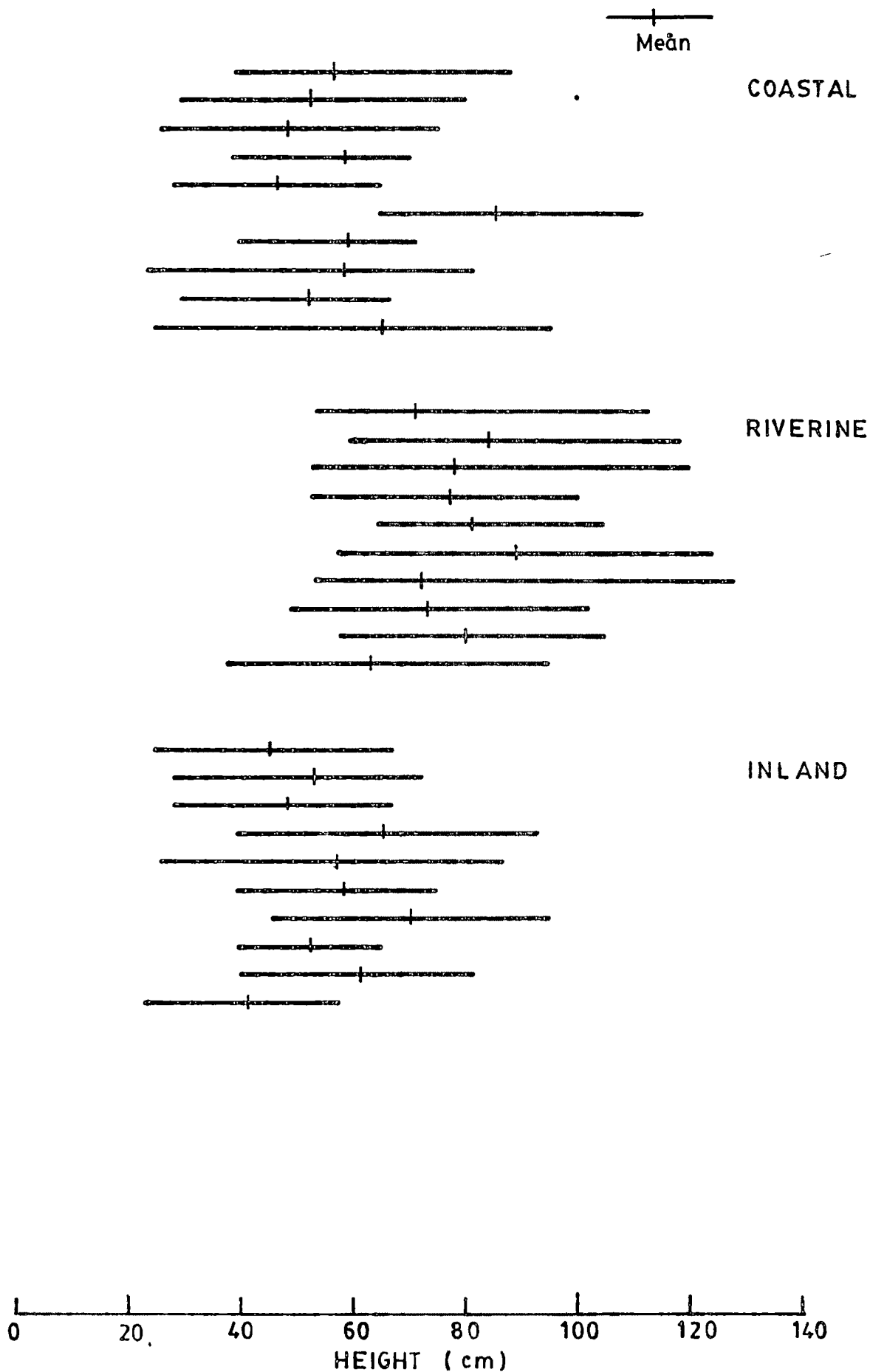


FIG. 6 FAMILY PERFORMANCE - HEIGHT 6 MONTH

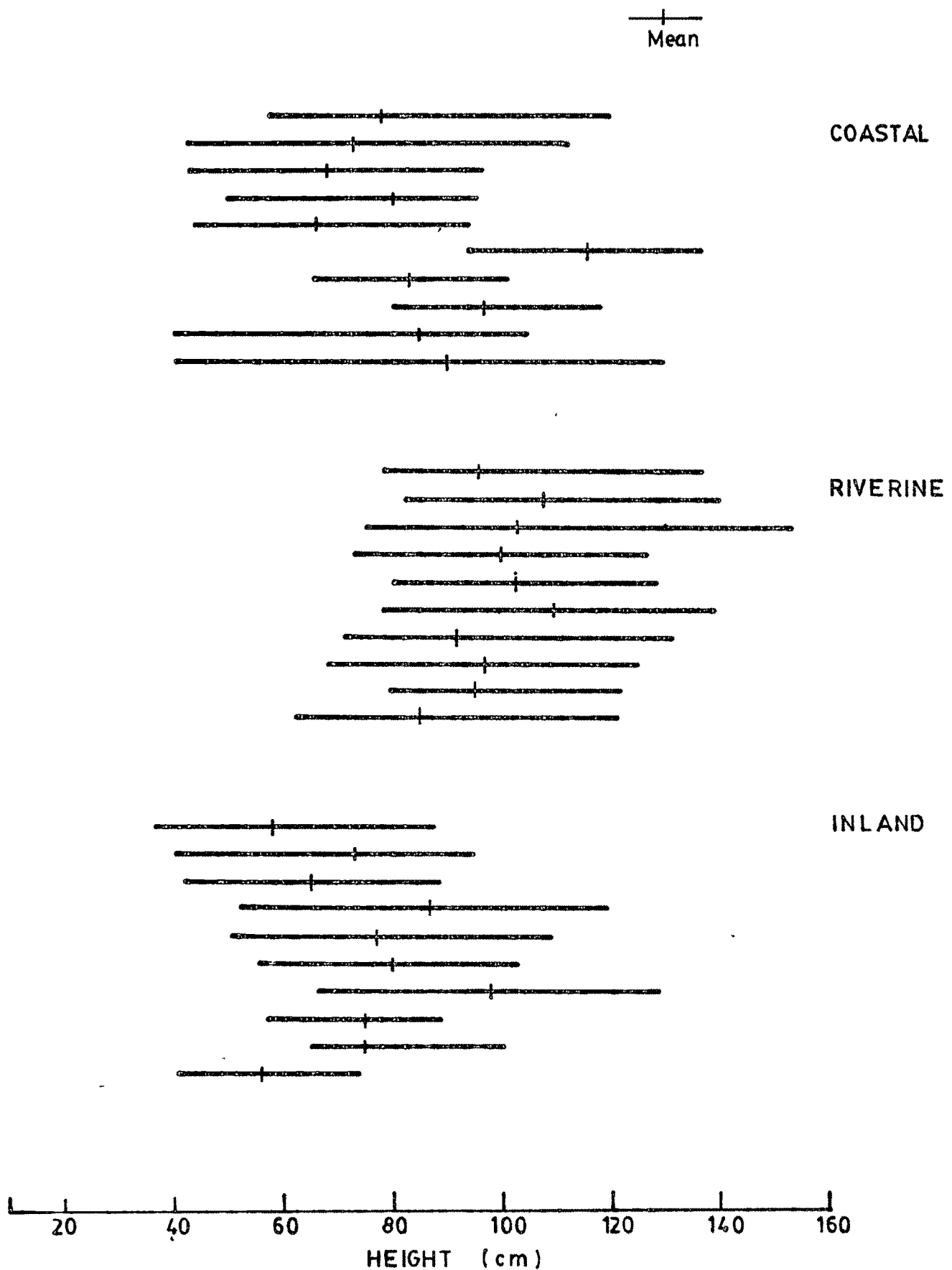


FIG. 7 FAMILY PERFORMANCE - HEIGHT AT 9 MONTH

Table 8. Growth of Casuarina of coastal, riverine and inland families -
Height at nine months

Family	Coastal	Family	Riverine	Family	Inland	Mean
1	78.73	11	96.31	21	58.20	77.70
2	73.26	12	107.64	22	72.53	84.47
3	67.15	13	103.35	23	66.66	79.04
4	80.26	14	98.78	24	87.20	88.74
5	65.95	15	104.66	25	77.20	82.59
6	116.47	16	109.80	26	80.66	102.31
7	83.20	17	91.66	27	98.00	90.95
8	77.20	18	96.66	28	74.93	82.93
9	85.00	19	94.52	29	82.00	87.17
10	90.00	20	85.10	30	56.26	77.12
Mean	81.71		98.84		75.36	

	SED	CD 5%
Family	3.12	6.25
Source	1.71	3.42
Family x Source	5.41	10.89

16 and the lowest of 115.7 by family 20. The families of inland sources showed comparatively slower growth rate with 98.0 cm as the mean with a range of 84.2 to 124.1 cm. The differences between the families and within the families were statistically significant (Table 9; Fig.8; Appendix III).

4.2.1.2. Diameter at collar

4.2.1.2.1. 6 months stage

The mean diameter for the families of coastal areas was 0.50 cm with a range of 0.37 to 0.74 cm, the highest being recorded by family 6. The riverine families showed thicker stems with a mean thickness of 0.65 cm. The maximum and minimum diameter encountered were 0.76 and 0.54 cm respectively. However, the inland families showed slightly improved trend with the mean at 0.51 cm while the minimum and maximum values were 0.38 and 0.68 cm respectively. Statistical evaluation indicated the differences between and within the families to be significant (Table 10; Fig.9; Appendix IV).

4.2.1.2.2. 9 months stage

The growth of seedlings from the families of coastal origin ranged from 0.50 to 0.69 cm with a mean of 0.61 cm. But the riverine sources showed faster growth registering a mean of 0.82 cm while the range was between 0.67 and 0.94 cm. The inland families performed better than the coastal sources by

Table 9. Growth of Casuarina of coastal, riverine and inland families -
Height at twelve months

Family	Coastal	Family	Riverine	Family	Inland	Mean
1	102.6	11	125.9	21	87.3	105.2
2	93.8	12	137.4	22	89.8	107.0
3	91.4	13	142.5	23	88.4	107.4
4	105.0	14	136.2	24	104.4	115.2
5	87.8	15	132.1	25	100.9	106.9
6	138.5	16	149.1	26	96.3	127.9
7	117.7	17	126.7	27	124.1	120.5
8	101.6	18	127.6	28	98.5	109.2
9	104.1	19	123.5	29	106.8	114.4
10	108.8	20	115.7	30	84.2	102.8
Mean	104.5		131.6		98.0	

Family	SED	CD
Source	2.927	5.886
Family x Source	1.689	3.398
	5.070	10.195

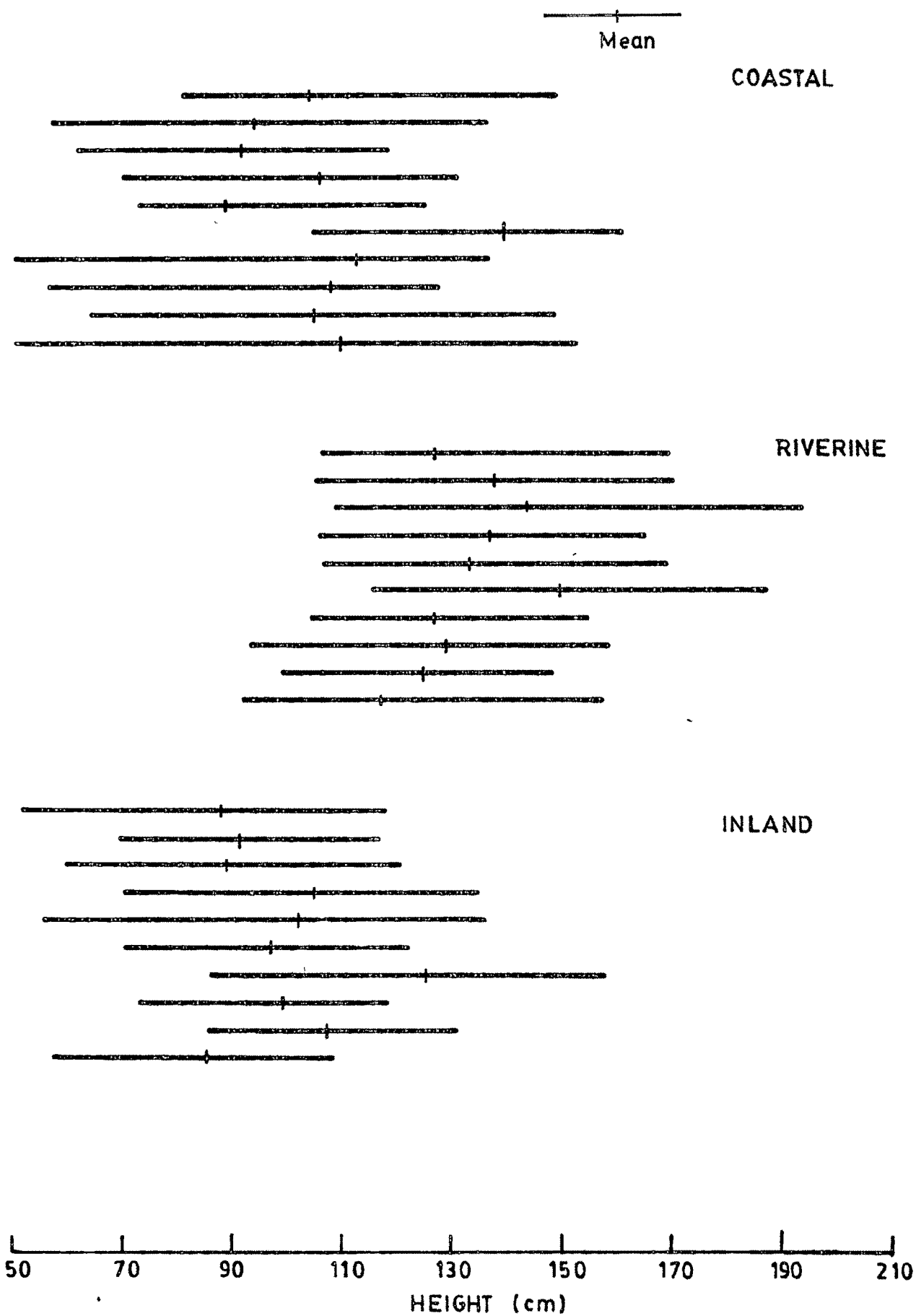


FIG. 8 FAMILY PERFORMANCE - HEIGHT AT 12 MONTH

Table 10. Growth of Casuarina of coastal, riverine and inland families -
Diameter at six months

Family	Coastal	Family	Riverine	Family	Inland	Mean
1	0.53	11	0.61	21	0.54	0.564
2	0.44	12	0.71	22	0.68	0.612
3	0.41	13	0.65	23	0.50	0.522
4	0.45	14	0.68	24	0.59	0.576
5	0.37	15	0.76	25	0.38	0.503
6	0.74	16	0.76	26	0.41	0.640
7	0.53	17	0.61	27	0.45	0.531
8	0.53	18	0.62	28	0.46	0.541
9	0.50	19	0.54	29	0.61	0.574
10	0.51	20	0.54	30	0.54	0.532
Mean	0.50		0.65		0.51	

Family	SED	CD 5%
Source	0.016	0.032
Family x Source	0.029	0.058
	0.050	0.101

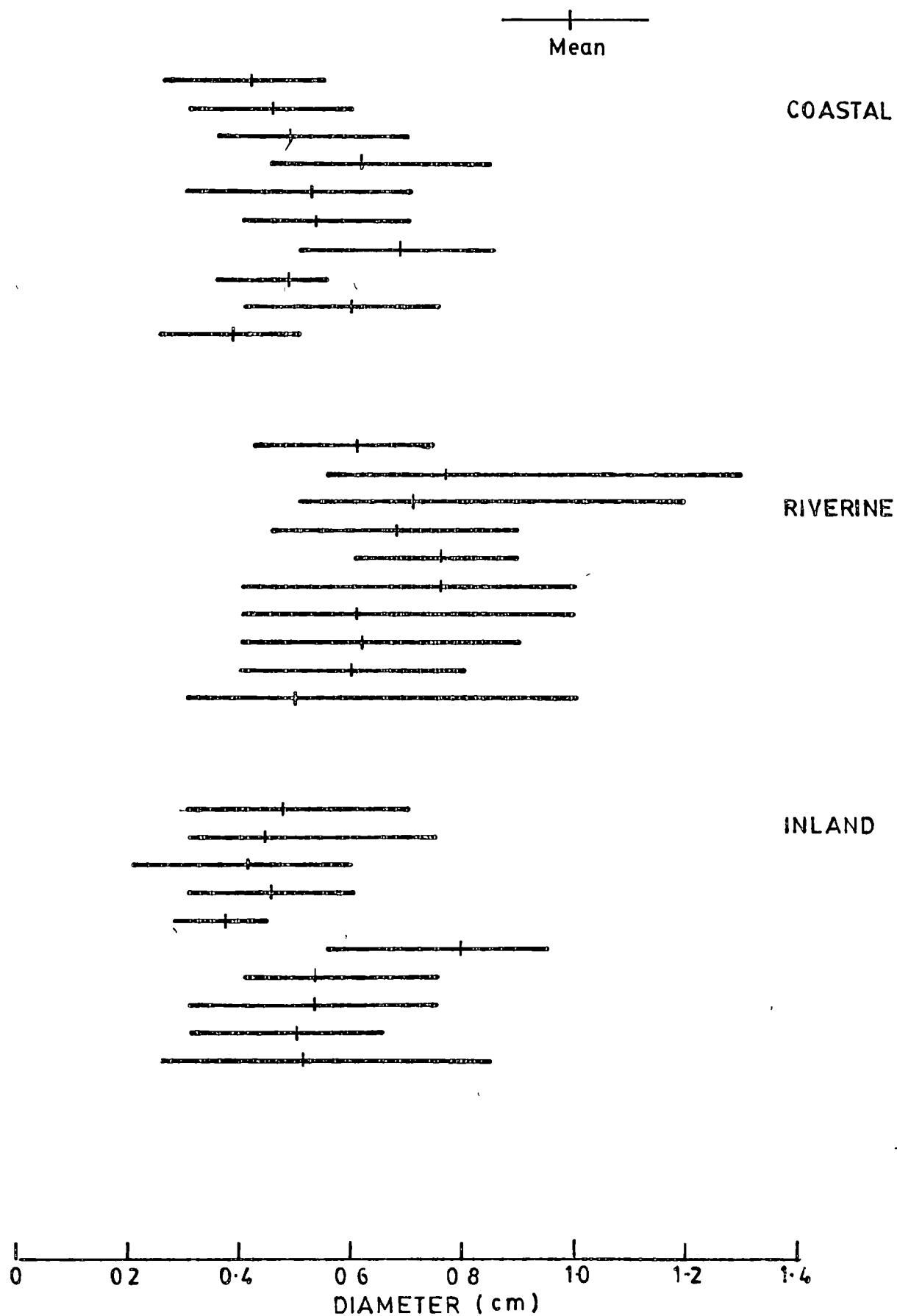


FIG. 9 FAMILY PERFORMANCE-DIAMETER AT 6 MONTH

recording a mean of 0.65 cm with a range of 0.52 to 0.83 cm. The statistical analysis showed significant differences between the families and individuals within a family (Table 11; Fig.10; Appendix V).

4.2.1.2.3. 12 months stage

The coastal families showed a mean of 0.92 cm followed by a maximum value of 1.03 cm and a minimum value of 0.80 cm. Similar situation was recorded for families obtained from riverine areas. They showed a mean value of 1.16 cm, and the range was between 1.03 and 1.33 cm. The inland families lagged behind despite their performance at 9 month stage and the families showed a mean of 0.87 cm with the maximum reported value of 1.10 and the minimum of 0.73 cm (Table 12; Fig.11; Appendix VI).

4.2.1.3. Number of branches

4.2.1.3.1. 6 months stage

The number of branches the plants putforth at this stage in the families of coastal sources ranged from 34.6 to 55.73 with a mean of 45.71. The number of branches increased in the case of families from riverine areas. The lowest was 46.45 and the highest was 78.06 while the mean for the families was at 68.78. The inland sources showed a mean of 50.50 with the range of 32.40 to 74.20. The differences in the number of

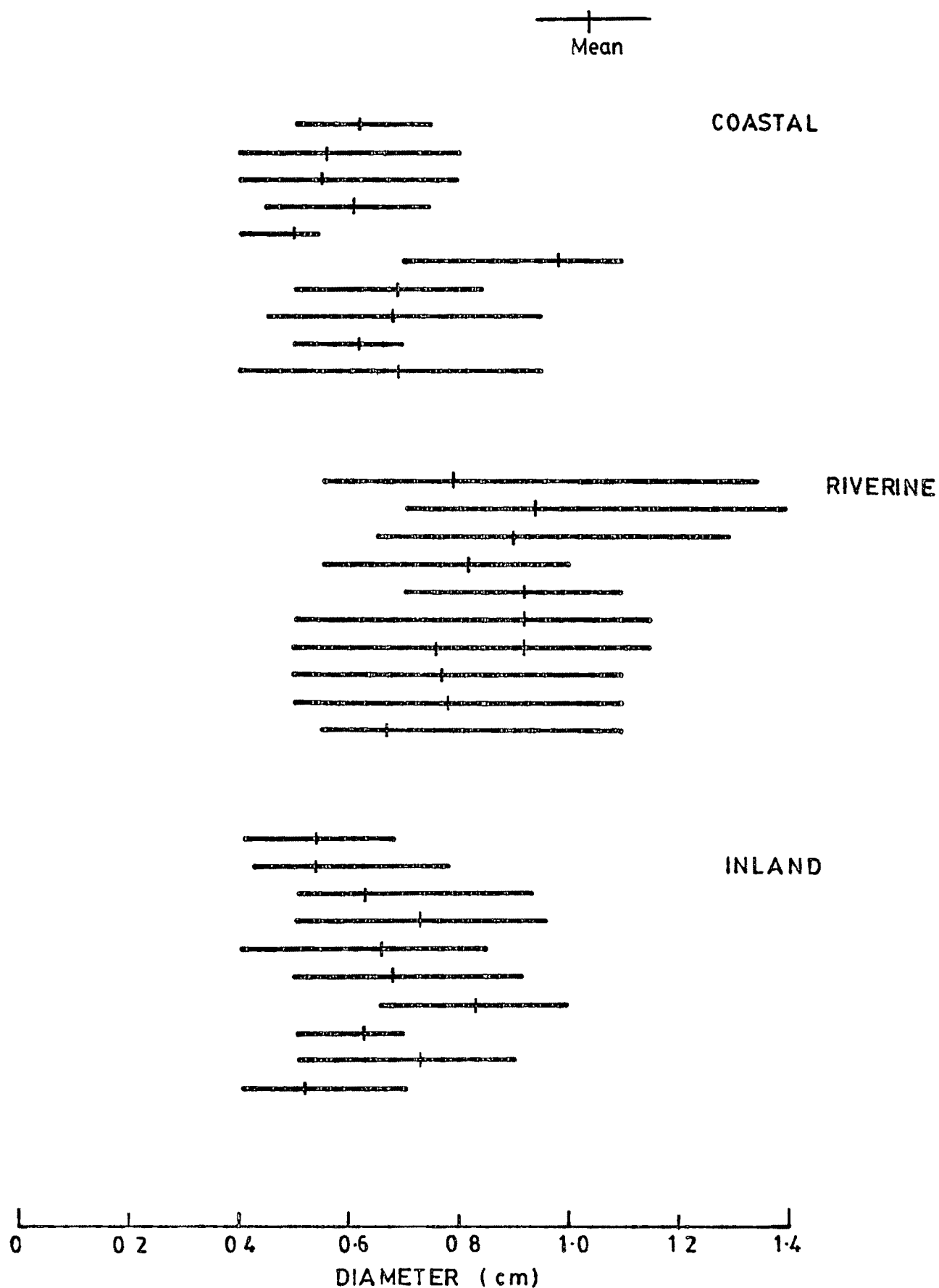
Table 11. Growth of Casuarina of coastal, riverine and inland families -
Diameter at nine months

Family	Coastal	Family	Riverine	Family	Inland	Mean
1	0.62	11	0.79	21	0.54	0.65
2	0.56	12	0.94	22	0.59	0.69
3	0.55	13	0.89	23	0.61	0.68
4	0.61	14	0.82	24	0.73	0.72
5	0.50	15	0.92	25	0.66	0.71
6	0.66	16	0.92	26	0.68	0.75
7	0.69	17	0.76	27	0.83	0.76
8	0.68	18	0.77	28	0.63	0.69
9	0.63	19	0.79	29	0.73	0.70
10	0.69	20	0.67	30	0.52	0.62
Mean	0.61		0.82		0.65	

Family Source Family x Source	SEd	CD 5%
	0.0173	0.0347
	0.0317	0.0635
	0.0549	0.1100

Table 12. Growth of Casuarina of coastal, riverine and inland families -
Diameter at twelve months

Family	Coastal	Family	Riverine	Family	Inland	Mean
1	0.90	11	1.17	21	0.73	0.93
2	0.80	12	1.20	22	0.83	0.94
3	0.83	13	1.20	23	0.76	0.93
4	1.00	14	1.26	24	0.96	1.07
5	1.00	15	1.33	25	0.86	1.06
6	1.03	16	1.03	26	0.86	1.07
7	0.90	17	1.16	27	1.10	1.05
8	0.93	18	1.13	28	0.86	0.97
9	0.86	19	1.13	29	1.03	1.01
10	1.00	20	1.03	30	0.73	0.92
Mean	0.92		1.16		0.87	
Family Source			SED	CD 5%		
Family x Source			0.0401	0.0806		
			0.0219	0.0440		
			0.0695	0.1396		



FIG, 10 FAMILY PERFORMANCE-DIAMETER AT 9 MONTH

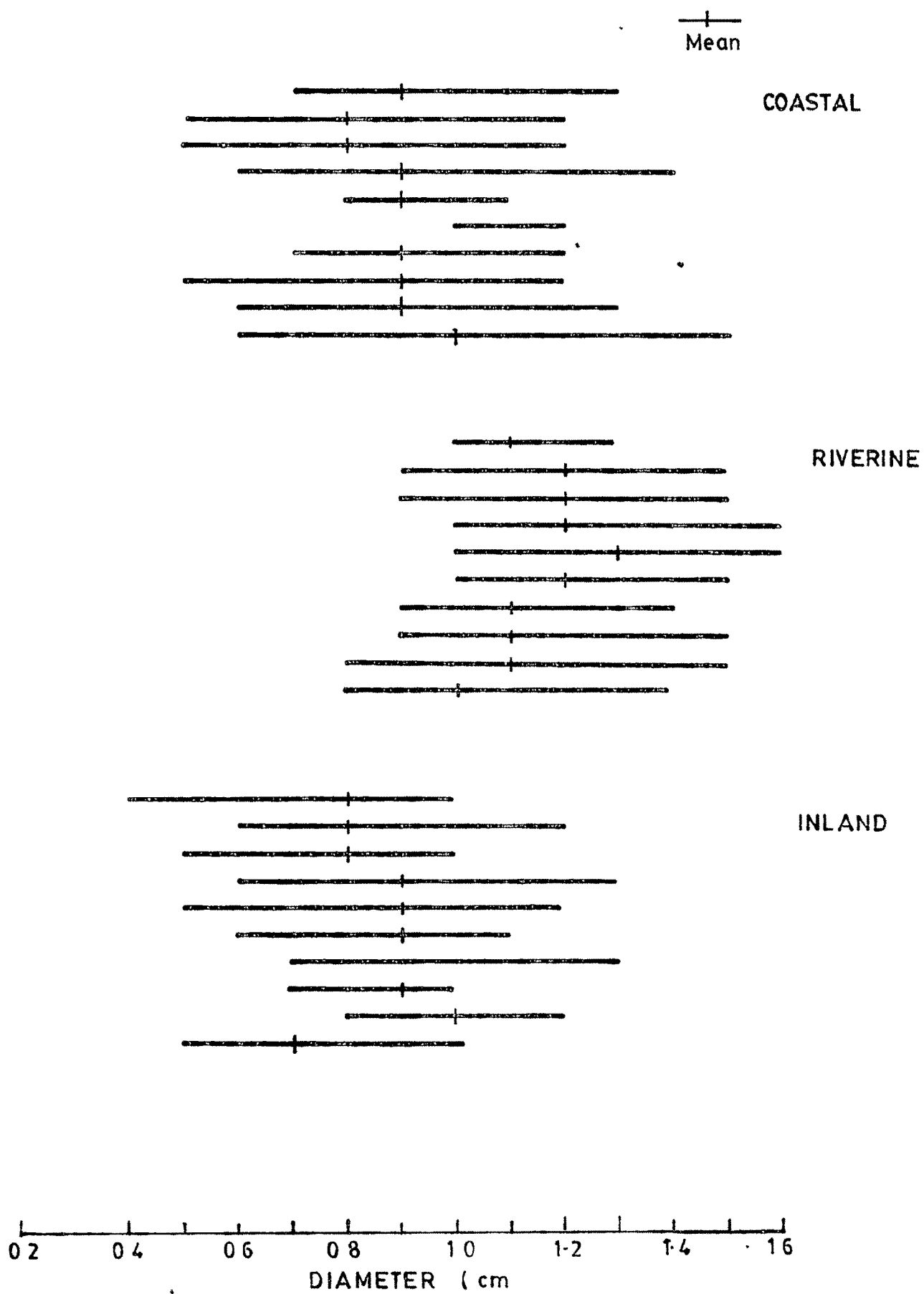


FIG.11 FAMILY PERFORMANCE- DIAMETER AT 12 MONTH

branches within and between the families were statistically significant (Table 13; Fig.12; Appendix VII).

4.2.1.3.2. 9 months stage

The branching pattern in the families of coastal source showed a mean of 73.89 with a range of 65.50 to 94.60 while the riverine families showed a mean of 99.73 with a considerably high range from a minimum of 74.23 to a maximum of 109.80. The inland sources had a mean of 81.11 while the minimum was 58.60 and maximum was 106.53 (Table 14; Fig.13; Appendix VIII).

4.2.1.3.3. 12 months stage

The number of branches ranged from 87.70 to 118.80 with a mean of 95.40 for the coast. The riverine families continued to show increase with a mean number of 127.90 branches where the minimum and maximum were 96.90 and 143.50 respectively. The inland sources showed a mean of 104.45 with a range of 84.70 to 126.70 branches. The differences in the number of branches both within and between the families were statistically significant (Table 15; Fig.14; Appendix IX).

4.2.1.4. Family x source interaction

4.2.1.4.1. Plant height

The family x source interaction revealed that family

Table 13. Growth of Gasuarina of coastal, riverine and inland families -
Number of branches at six months

Family	Coastal	Family	Riverine	Family	Inland	Mean
1	49.46	11	77.40	21	36.06	54.31
2	37.46	12	76.20	22	46.00	53.22
3	40.46	13	71.73	23	45.93	52.71
4	55.73	14	63.06	24	61.66	60.13
5	34.60	15	71.06	25	48.46	51.37
6	61.66	16	69.40	26	50.00	60.35
7	42.80	17	66.93	27	74.20	61.31
8	45.20	18	78.06	28	49.33	57.53
9	44.33	19	67.46	29	60.93	57.57
10	45.40	20	46.46	30	32.40	41.42
Mean	45.71		68.78		50.50	

CD 5%

SED

Family
Source
Family x Source

3.04
1.66
5.27

6.09
3.33
10.55

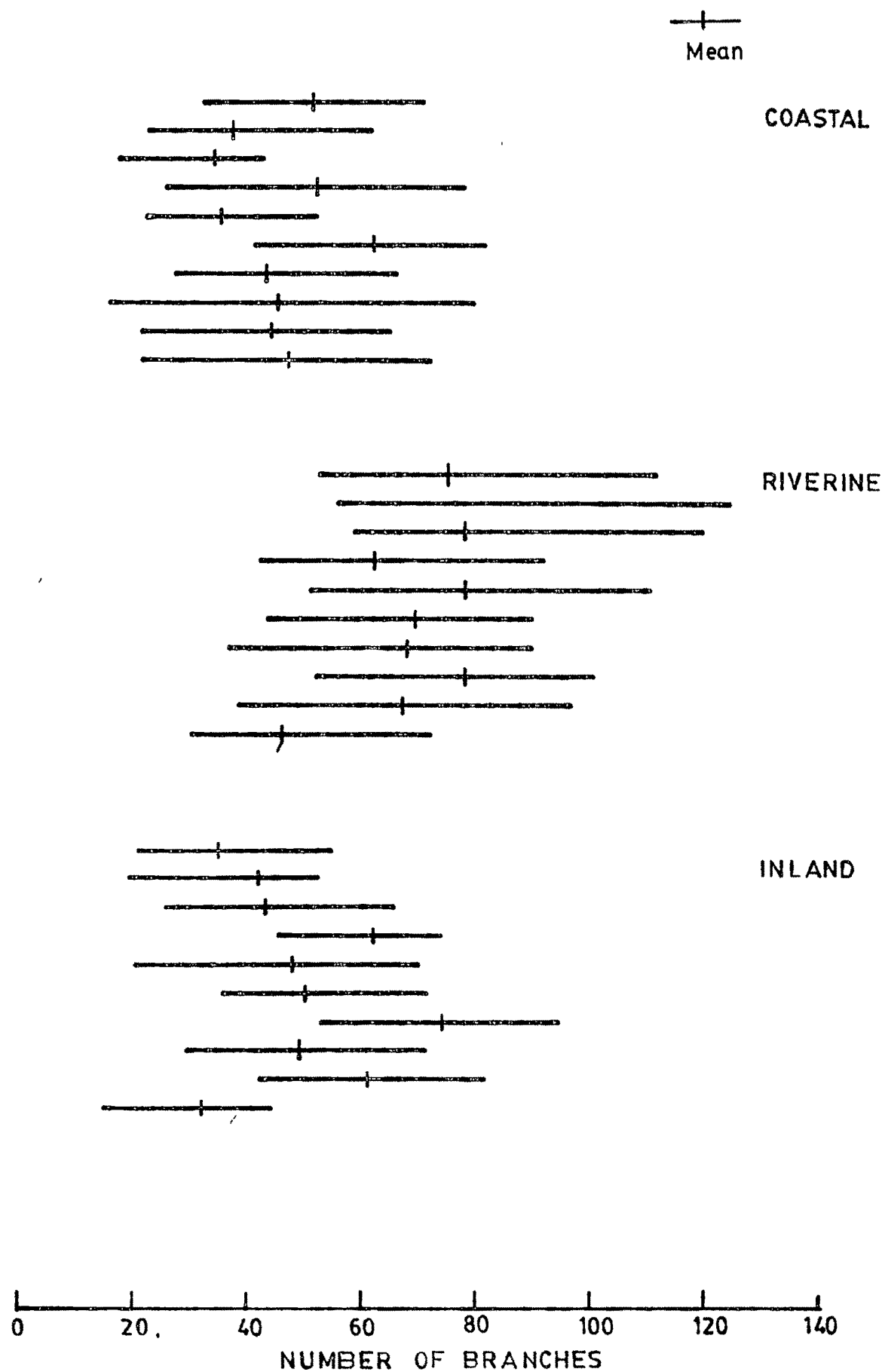


FIG. 12 FAMILY PERFORMANCE- BRANCHES AT 6 MONTH

Table 14. Growth of Casuarina of coastal, riverine and inland families -
Number of branches at nine months

Family	Coastal	Family	Riverine	Family	Inland	Mean
1	75.61	11	109.80	21	58.86	81.44
2	66.93	12	106.70	22	68.53	80.72
3	65.60	13	108.28	23	76.40	83.42
4	81.60	14	97.93	24	103.46	94.33
5	65.00	15	105.60	25	82.06	84.22
6	94.60	16	94.93	26	82.20	90.57
7	69.40	17	97.20	27	106.53	91.04
8	71.80	18	107.80	28	81.73	87.11
9	71.00	19	94.93	29	92.60	86.17
10	77.40	20	74.23	30	58.80	70.14
Mean	73.89		99.73		81.11	

	SED	CD 5%
Family	3.55	7.12
Source	1.94	3.90
Family x Source	6.16	12.33

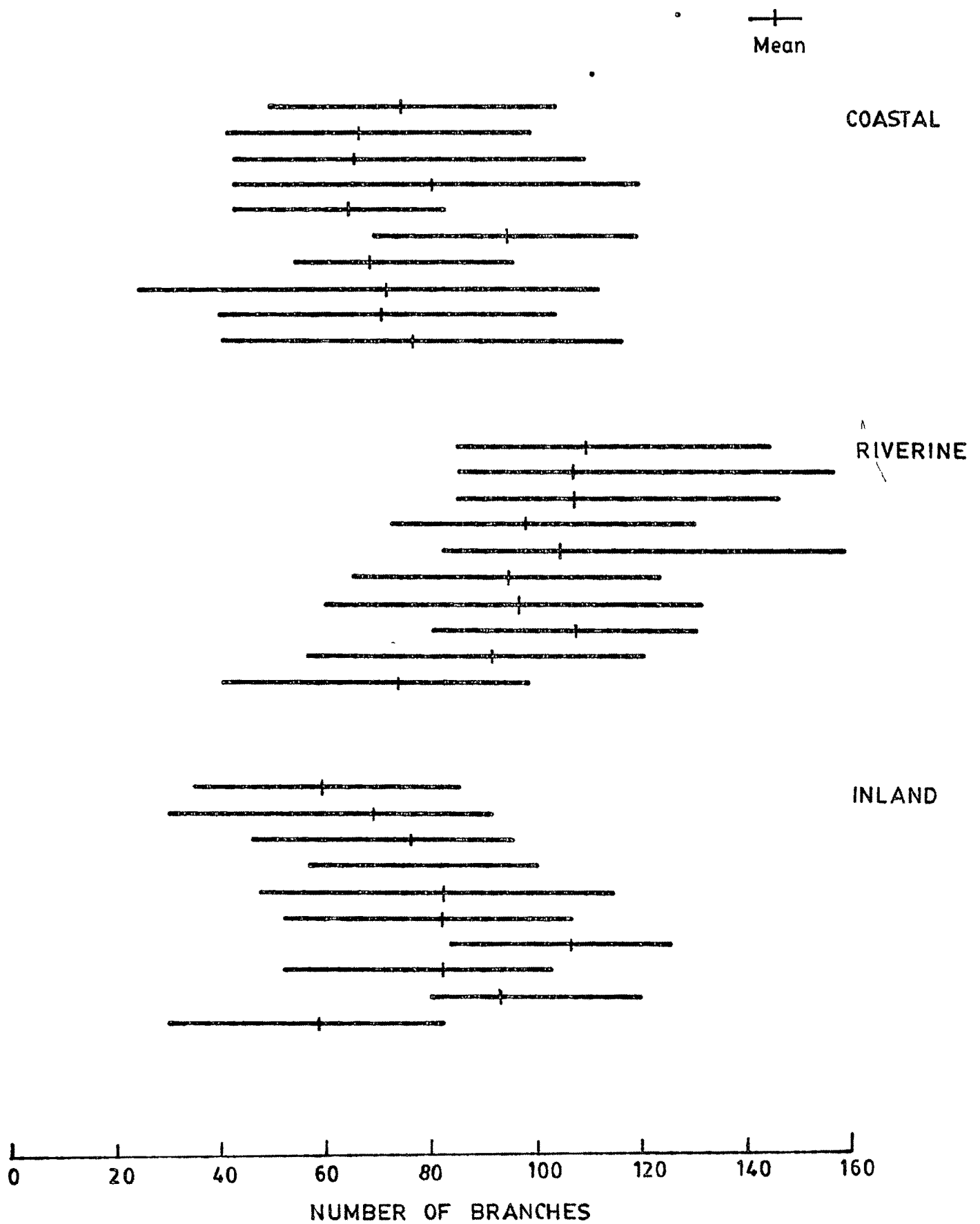


FIG. 13 FAMILY PERFORMANCE - BRANCHES AT 9 MONTH

Table 15. Growth of Casuarina of coastal, riverine and inland families -
Number of branches at twelve months

Family	Coastal	Family	Riverine	Family	Inland	Mean
1	96.4	11	140.0	21	86.8	107.8
2	90.1	12	132.0	22	93.2	105.1
3	87.9	13	132.8	23	98.2	106.3
4	103.4	14	128.6	24	126.7	119.6
5	87.7	15	143.5	25	110.6	113.9
6	118.8	16	130.3	26	113.1	120.7
7	91.8	17	121.8	27	121.4	111.6
8	92.9	18	134.4	28	106.6	111.3
9	91.7	19	119.6	29	104.5	105.3
10	93.5	20	96.9	30	84.7	91.7
Mean	95.4		127.9		104.4	

SED CD 5%

Family
Source
Family x Source

3.12
1.70
5.40

6.27
3.44
10.87

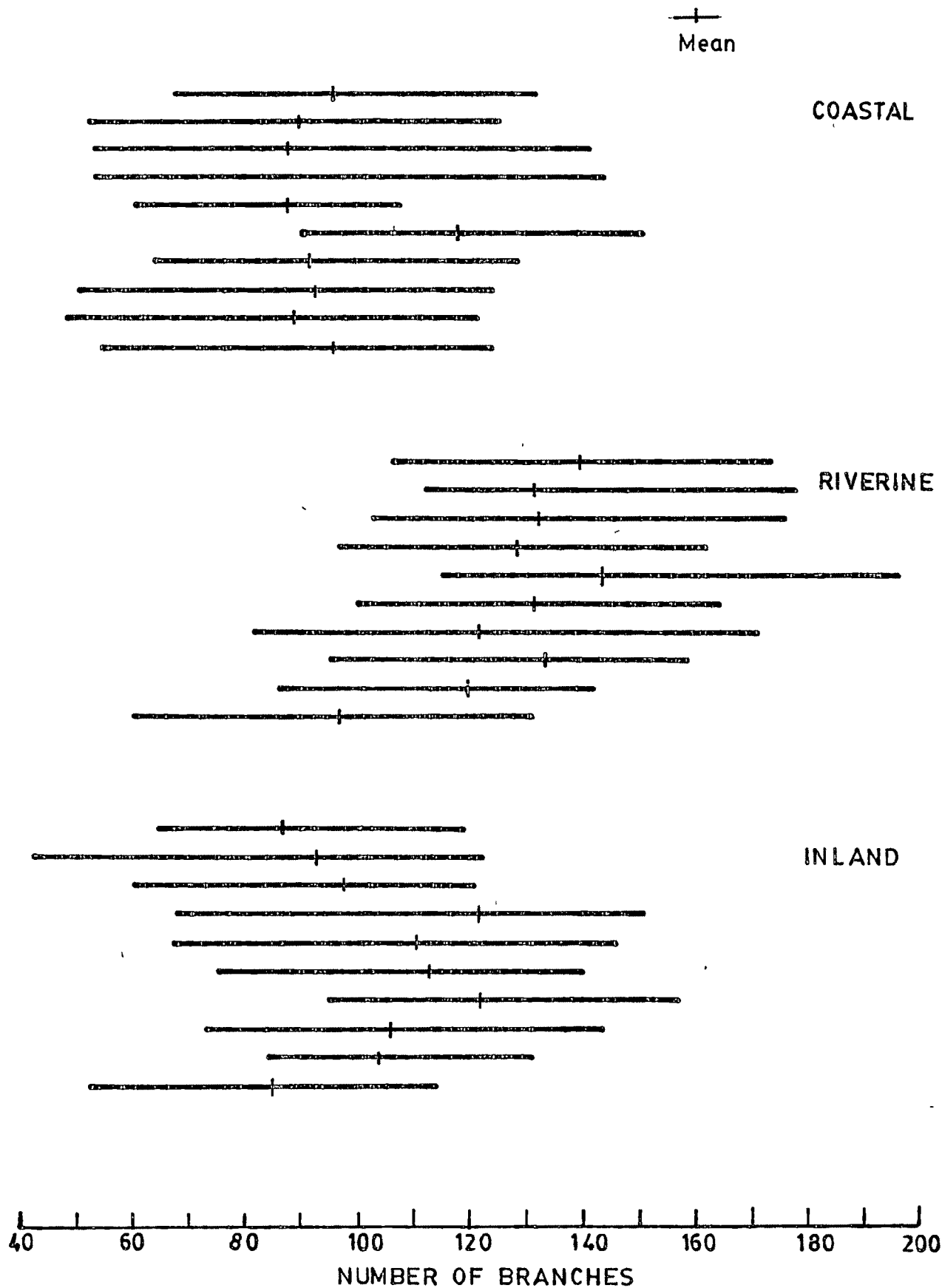


FIG.14 FAMILY PERFORMANCE- BRANCHES AT 12 MONTH

6 (coastal) to be superior for height at six months stage recording 85.13 cm and also at nine months stage (116.47 cm) but at twelve months stage family 16 (riverine) showed maximum height growth, followed by family 6. This indicated a differential rate of development between the families. Yet, families 6, 12, 15, 16 and 19 were all on par statistically at six months stage. At the nine months stage, families 6, 12 and 16 were only on par. Among the coastal families, family 27 was foremost. When the families were assessed at the twelve month stage, the riverine families showed faster growth. Family 16 was leading others but was not on par with other families. Family 6 from coast, and family 27 from inland were the leading families for their locations.

4.2.1.4.2. Diameter at collar

The consideration of diameter growth at collar for the different stages of growth reflected variable growth pattern of the selections. The riverine selections 15 and 16 that were leading at the six month stage, lagged behind subsequently. However, the families 2, 6, 14, 15, 16 and 22 were all on par statistically. At the nine month stage, family 12 was showing dominant growth but was on par with families 13, 15, 16 and 27. None of the coastal families could show this growth.

The trend changed at twelve months stage when family 15 was leading but was on par with 12, 13 and 14. The coastal and inland families lagged behind considerably.

4.2.1.4.3. Number of branches

The mean number of branches at six months growth was highest for family 18 from riverine sources (78.06). However, it was on par with other families 11, 12, 13, 14, 15, 18, 24 and 27 despite family 11 leading with 109.8 branches. The situation shifted differently at twelve months stage when the riverine families 11, 12, 13, 15, 16 and 18 stood on par and showed dominant growth with 130.3-143.5 branches. Among the coastal families, family 6 was foremost with 118.8 branches and family 24 in inland source was leading with 126.7 branches.

4.2.2. PER SE PERFORMANCE AND STABILITY PARAMETERS

Mean performance of the single family selections and the stability parameters for three characters viz., plant height, diameter at collar and number of branches per growth period of the plants are presented in Tables 16, 17 and 18 (Fig.15, 16 and 17).

4.2.2.1. Plant height

4.2.2.1.1. Per se performance in 6 months growth period

In 6 months growth phase, the general height was

Table 16. Stability parameters for tree height in cm

Family	6 month growth	9 month growth	12 month growth	Mean	Regression coefficient b	Mean square deviation S_d^2
1	55.9	78.7	102.6	79.0	0.9617	-12.5760
2	51.7	73.2	93.8	72.9	0.8659	-10.6497
3	47.9	67.1	91.4	68.8	0.8972	-13.1605
4	57.5	80.2	105.0	80.9	0.9794	-13.1984
5	45.8	65.9	87.8	66.5	0.8659	-13.2624
6	85.1	116.4	138.5	113.3	1.0935	16.3987
7	58.7	83.2	117.7	86.5	1.0937	-13.6360
8	57.6	77.2	101.6	78.8	0.9081	-13.2533
9	51.9	85.0	104.1	80.3	1.0670	40.1437
10	64.6	90.0	108.8	87.8	0.9061	3.1045
11	70.4	96.3	125.9	97.5	1.1444	-13.5995
12	84.5	107.6	137.4	109.8	1.0931	-12.4861
13	77.4	103.3	142.5	107.7	1.3485	-2.3020
14	73.3	98.7	136.2	102.7	1.2208	7.9945
15	80.9	104.6	132.1	105.8	1.0551	-13.6240
16	88.9	109.8	149.1	115.9	1.2503	18.3404
17	71.5	91.6	125.7	96.2	1.1237	2.2174
18	73.6	96.6	127.6	99.2	1.1177	-11.2683
19	80.3	94.5	123.5	99.4	0.8969	-8.1521
20	63.0	85.1	115.7	87.9	1.0899	-10.2506
21	45.0	58.2	87.3	63.5	0.8749	13.7430
22	53.0	72.5	89.8	71.7	0.7568	-9.5353
23	46.0	66.6	88.4	67.0	0.8632	-13.2675
24	64.9	87.2	104.4	85.5	0.8115	-2.5182
25	57.3	77.2	100.9	78.4	0.8993	-13.5975
26	85.1	80.6	96.3	87.3	0.7805	1.8944
27	58.7	98.0	124.1	93.6	1.1039	-8.7367
28	57.6	74.9	98.5	77.0	1.0858	2.5621
29	51.9	82.0	106.8	80.2	0.9487	-13.6316
30	64.6	56.2	84.2	68.3	0.8964	0.8820
Mean	64.1	85.2	111.5	86.9	0.9	
SEd	9.3	10.8	13.3	10.6	0.1	

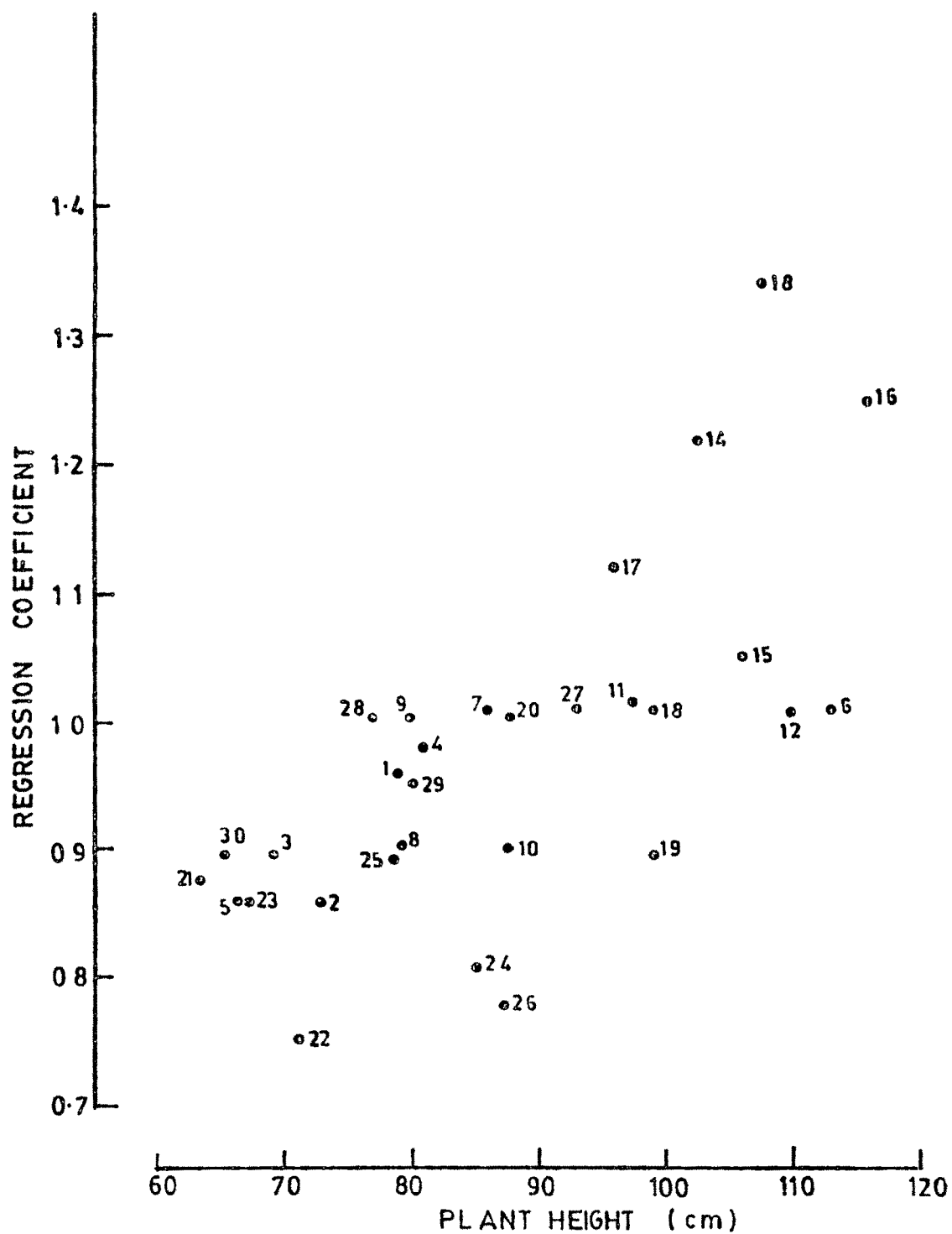


FIG.15 DIFFERENTIAL RESPONSIVENESS OF SINGLE FAMILIES -
HEIGHT OF PLANT

Table 17. Stability parameters for tree diameter in cm

Family	6 month growth	9 month growth	12 month growth	Mean	Regression coefficient _b	Mean square deviation $-S_d^2$
1	0.53	0.62	0.90	0.68	0.8573	-0.0008
2	0.44	0.56	0.80	0.60	0.8328	-0.0019
3	0.41	0.55	0.83	0.59	0.9666	-0.0018
4	0.45	0.61	1.00	0.68	1.2768	-0.0012
5	0.37	0.50	1.00	0.62	1.4956	0.0035
6	0.74	0.66	1.03	0.87	0.6203	0.0062
7	0.53	0.69	0.90	0.70	0.8315	-0.0011
8	0.53	0.68	0.93	0.71	0.9144	-0.0019
9	0.50	0.63	0.86	0.66	1.0054	-0.0014
10	0.53	0.69	1.00	0.73	1.1147	-0.0019
11	0.61	0.79	1.17	0.85	1.2858	-0.0017
12	0.71	0.94	1.20	0.95	1.0910	0.0002
13	0.65	0.89	1.20	0.91	1.2480	-0.0003
14	0.68	0.82	1.26	0.92	1.3679	0.0008
15	0.76	0.92	1.33	1.00	1.3411	-0.0009
16	0.76	0.92	1.03	0.93	0.6029	0.0008
17	0.61	0.76	1.16	0.84	1.3029	-0.0009
18	0.62	0.77	1.13	0.84	1.1856	-0.0011
19	0.54	0.79	1.13	0.82	1.2186	-0.0019
20	0.54	0.67	1.03	0.74	1.1557	-0.0010
21	0.54	0.54	0.73	0.60	0.7260	-0.0018
22	0.68	0.59	0.83	0.70	0.8830	-0.0019
23	0.50	0.61	0.76	0.62	0.6895	-0.0007
24	0.59	0.73	0.96	0.76	0.8179	-0.0019
25	0.38	0.66	0.86	0.63	0.7521	-0.0019
26	0.41	0.68	0.86	0.65	0.7350	-0.0014
27	0.45	0.83	1.10	0.79	0.9675	-0.0019
28	0.46	0.63	0.86	0.65	0.8785	-0.0017
29	0.61	0.73	1.03	0.79	1.0294	-0.0018
30	0.54	0.52	0.73	0.63	0.8060	-0.0016
Mean	0.55	0.71	0.98	0.74	1.00	
SEd	0.07	0.07	0.11	0.07	0.16	

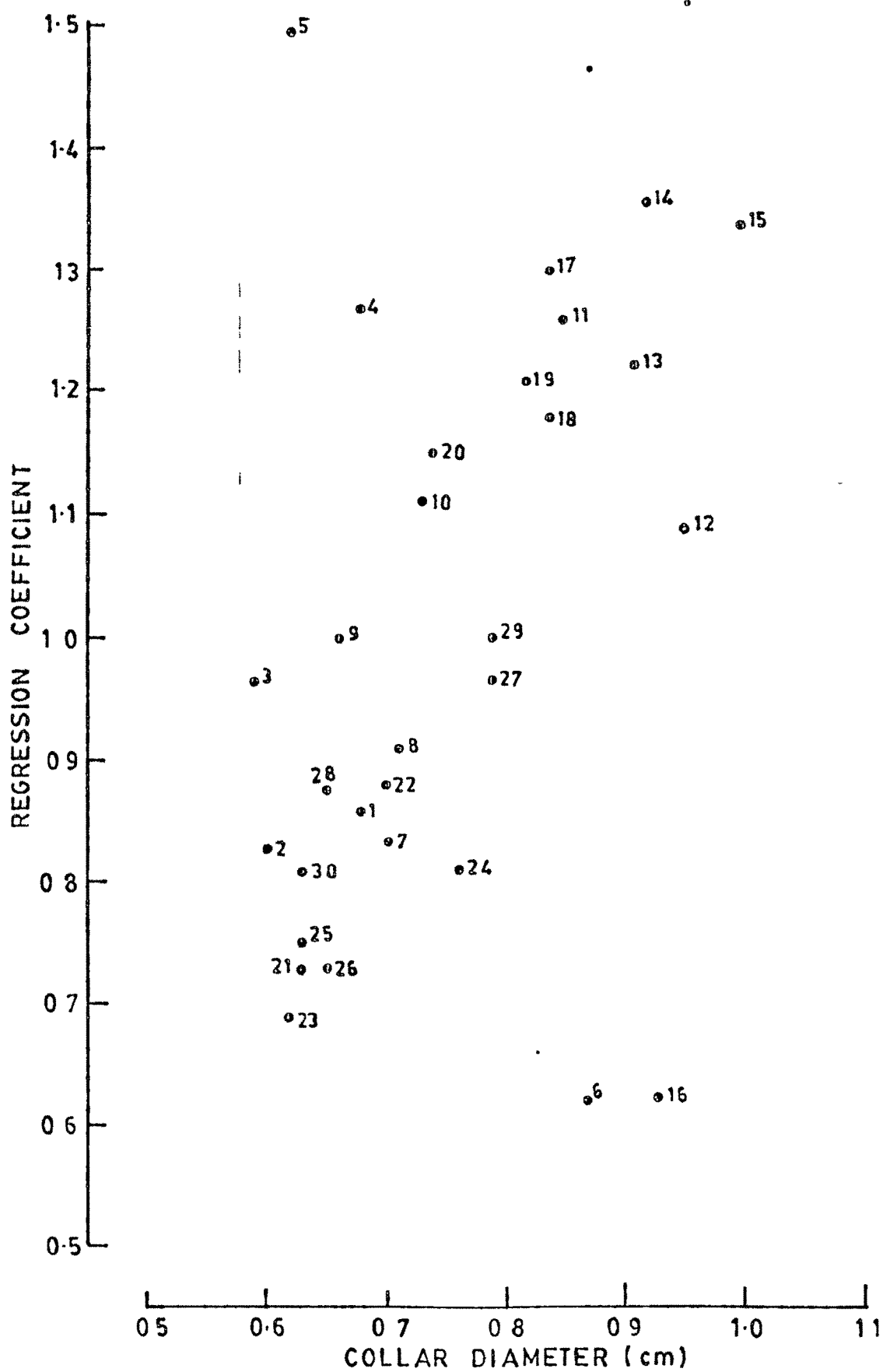


FIG. 16 DIFFERENTIAL RESPONSIVENESS OF SINGLE FAMILIES- DIAMETER OF COLLAR

Table 18. Stability parameters for number of branches

Family	6 month growth	9 month growth	12 month growth	Mean	Regres- sion co- effici- ent _b	Mean square deviation $\bar{S}_d^2$
1	49.4	75.6	96.4	73.8	0.8667	-14.8980
2	37.4	66.9	90.1	64.8	0.9719	-14.8136
3	40.4	65.6	87.9	64.6	0.8731	-14.4518
4	55.7	81.6	103.4	80.2	0.8793	-14.9244
5	34.6	65.0	87.7	62.4	0.9813	-14.0301
6	61.6	94.6	118.8	91.6	1.0681	-12.7347
7	42.8	69.4	91.8	68.0	0.9096	-14.9822
8	45.2	71.8	92.9	69.9	0.8808	-14.9087
9	44.3	71.0	91.7	69.0	0.8743	-14.7278
10	45.4	77.4	93.5	72.1	0.8944	5.5001
11	77.4	109.8	140.0	109.0	1.1519	-12.3742
12	76.2	106.7	132.0	104.9	1.0283	-14.9946
13	71.7	108.2	132.8	104.2	1.0026	-15.0017
14	63.0	97.9	128.6	96.5	1.2064	-14.1770
15	71.0	105.6	143.5	106.7	1.3292	3.3427
16	69.4	94.9	130.3	98.2	1.1123	26.3160
17	66.9	97.2	121.8	95.3	1.0119	-14.9914
18	78.0	107.8	134.4	106.7	1.0368	-14.0509
19	67.4	94.9	119.6	93.9	0.9594	-14.1124
20	46.4	74.2	96.9	72.5	0.9296	-14.9937
21	36.0	58.8	86.8	60.5	0.9479	6.1404
22	46.0	68.5	93.2	69.2	0.8658	-7.4029
23	48.9	76.4	98.2	74.5	0.9654	-12.9198
24	61.6	103.4	126.7	97.2	1.2071	9.3804
25	48.4	82.0	110.6	80.3	1.1451	-14.8134
26	60.0	82.2	113.1	85.1	1.1612	-10.9104
27	74.2	106.5	121.4	100.7	0.8770	12.5314
28	49.3	81.7	106.6	79.2	1.0882	-13.0592
29	60.9	92.6	104.5	86.6	0.8128	24.6894
30	32.4	58.8	84.7	58.6	0.9617	-11.3838
Mean	55.39	84.58	110.23	83.18	1.00	
SEd	9.87	11.57	13.20	11.30	0.08	

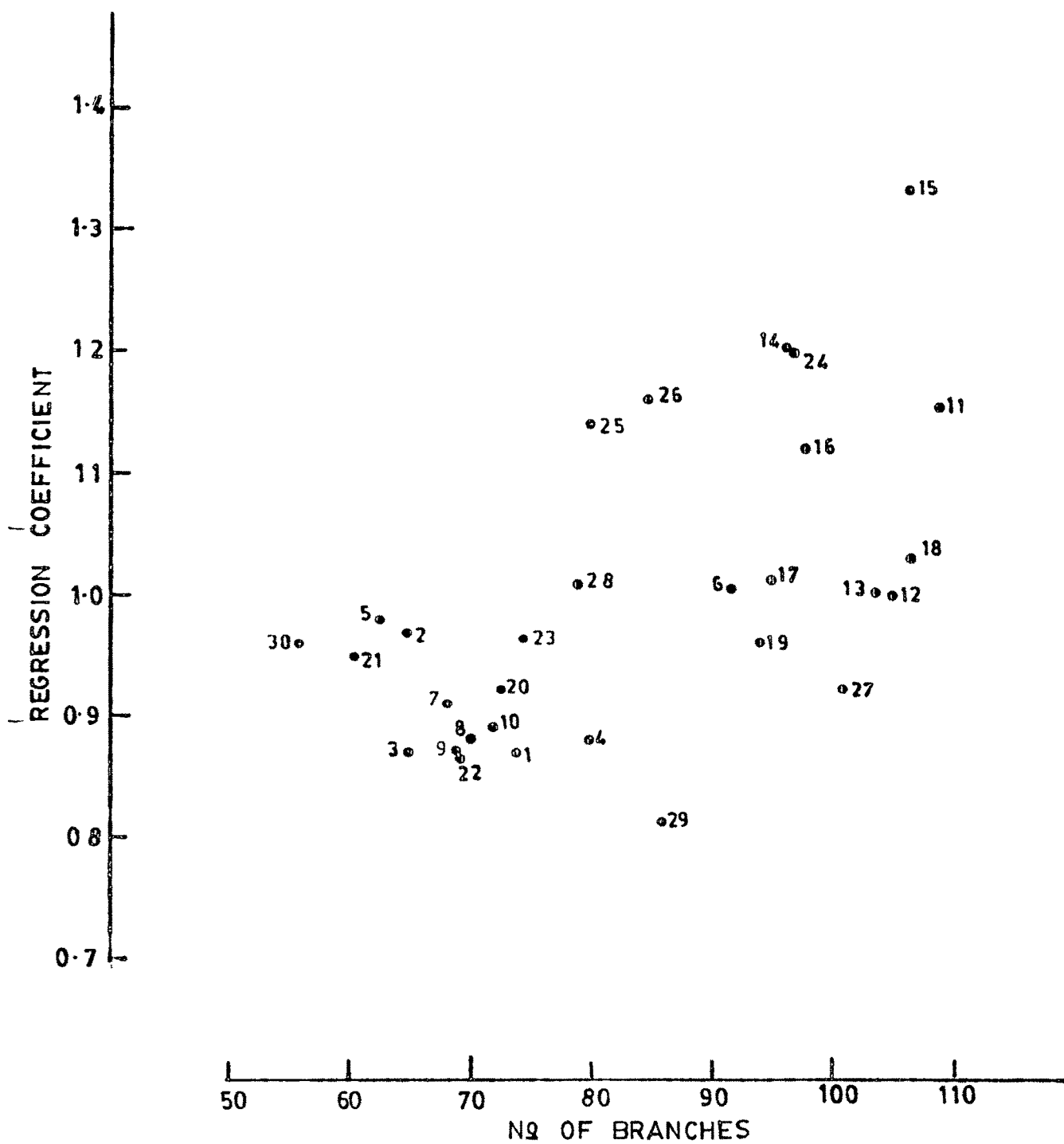


FIG. 17 DIFFERENTIAL RESPONSIVENESS OF SINGLE FAMILIES-
NUMBER OF BRANCHES

64.1 cm. The height of single family ranged from 45.0 to 88.9 cm. The later was recorded by family 16. Six other family selections viz., 6, 12, 13, 15, 19 and 26 recorded plant heights higher than the general mean (m) plus one standard error (SE).

4.2.2.1.2. Per se performance in 9 months growth period

The plant height of single family ranged from 56.2 to 116.4 cm with the general mean at 85.2 cm. The single family 6 recorded the maximum plant height (116.4 cm) while eight other families recorded heights of more than the mean + one standard error.

4.2.2.1.3. Per se performance in the 12 months growth period

The general mean height was 111.5 cm with a range of 84.2 to 149.1 cm. Eight selections recorded higher plant height than the general mean plus one standard error where family 16 recorded the maximum height.

4.2.2.1.4. Stability parameters

4.2.2.1.4.1. Mean performance over growth periods

The general mean over growth periods was 86.9 cm. The mean plant height ranged from 63.5 to 115.9 cm. Nine families viz., Family 6, 11, 12, 13, 14, 15, 16, 18 and 19

recorded mean values higher than mean value plus one standard error.

4.2.2.2. Plant diameter

4.2.2.2.1. Per se performance in 6 months growth period

In 6 months growth phase, the general diameter of the plant at collar was 0.55 cm. The diameter of the single family ranged from 0.37 to 0.76 cm. The highest value was recorded by family 15 and 16. Six other families recorded diameter greater or equal to the general mean + one standard error.

4.2.2.2.2. Per se performance in 9 months growth period

The average diameter recorded for this growth period was only 0.71 cm with a range of 0.50 to 0.94 cm. The highest value was recorded by family 12. Eight families recorded values higher than mean plus one standard error.

4.2.2.2.3. Per se performance in 12 months growth period

The growth at this period recorded a mean of 0.98 cm. The lowest growth in diameter was exhibited by family 30 recording 0.73 cm while family 15 recorded the maximum of 1.33 cm. Nine families showed higher values exceeding the mean plus one standard error.

4.2.2.2.4. Stability parameter

4.2.2.2.4.1. Mean performance over growth period

The ^{overall} growth mean over growth periods was 0.74 cm. The mean plant diameter ranged from 0.59 to 1.00, the later recorded by family 15. Ten families showed superior growth over the mean plus one standard error. Five families, family 12, 13, 14, 15 and 16 showed much superior growth of one mean plus two standard errors.

4.2.2.3. Number of branches

4.2.2.3.1. Per se performance in 6 months growth period

The mean number of branches occurring at this stage was 55.39 with family 30 showing the least (32.4) and family 18 showing the maximum (78.0). Nine families showed branch numbers higher than mean plus one standard error.

4.2.2.3.2. Per se performance in 9 months growth period

The mean number of branches at this growth stage was recorded as 84.68 with a range of 58.8 (family 21) and 30 to 109.8 (family 11). Nine families showed values higher than mean plus one standard error.

4.2.2.3.3. Per se performance in 12 months growth period

The families showed an overall value of 110.23 as mean but it ranged from 84.7 (family 30) to 143.5 (family 1)

Eight families showed values higher than the mean + one standard error.

4.2.2.3.4. Stability parameter

4.2.2.3.4.1. Mean performance over the growth periods

The grand mean over growth periods was 83.18 with a range of 58.6 to 109.0 recorded by family 30 and family 11 respectively. Nine families showed superior performance that registered more than the mean plus one standard error. Among the nine, seven were from the riverine and two from the inland areas.

4.2.3. Genetic Divergence

4.2.3.1. D^2 Analysis

The thirty families were grouped into eight clusters at 12 months growth phase. The constituents of different clusters are indicated in Table 19. Among the clusters, Cluster I was largest having eleven single families followed by Cluster III having six families and four families each in the Cluster II and IV. Cluster V had two and the Clusters VI, VII and VIII had one each.

4.2.3.1.1. Mean values of different clusters

The cluster mean values for the three characters showed wide differences among the clusters.

Table 19. D^2 analysis - Clusters and mean values

S. No.	Cluster	Family No.	Height cm	Diameter cm	Branches
1.	I	1	79.0	0.68	73.8
2.		4	80.9	0.68	80.2
3.		7	86.5	0.70	68.0
4.		8	78.8	0.71	69.9
5.		9	80.3	0.66	69.0
6.		10	87.8	0.73	72.1
7.		20	87.9	0.74	72.5
8.		25	78.4	0.63	80.3
9.		26	87.3	0.65	85.1
10.		28	77.0	0.65	79.2
11.		29	80.2	0.79	86.0
	Mean		82.2	0.89	76.0
12.	II	17	96.2	0.84	95.3
13.		18	99.2	0.84	106.7
14.		19	99.4	0.82	93.9
15.		27	93.6	0.79	100.7
	Mean		97.1	0.82	99.1
16.	III	2	72.9	0.60	64.8
17.		3	68.8	0.59	64.6
18.		21	63.5	0.63	60.5
19.		22	71.7	0.70	69.2
20.		23	67.0	0.62	74.5
21.		30	68.3	0.63	58.6
	Mean		68.7	0.62	65.3
22.	IV	11	97.5	0.85	109.0
23.		12	109.8	0.95	104.9
24.		13	107.7	0.91	104.2
25.		14	102.7	0.92	96.5
	Mean		104.4	0.90	103.6
26.	V	6	113.3	0.87	91.6
27.		16	115.9	0.93	98.2
	Mean		114.6	0.90	94.9
28.	VI	5	66.5	0.62	62.4
29.	VII	15	109.8	1.00	106.7
30.	VIII	24	85.5	0.76	97.2

Cluster I had a mean value for plant height at 82.20 cm, mean diameter at 0.69 cm and the mean for branches 76.00.

Cluster III, the next largest group, showed mean height of 68.7 cm, mean diameter 0.62 cm and mean number of branches 65.36.

Cluster II exhibited higher mean values than the above two. The mean values of 97.1 cm, 0.82 cm, and 99.10 were recorded for height, diameter and number of branches respectively.

Cluster IV comprising only four families showed high values among all the clusters recording a mean height of 104.4 cm, diameter of 0.90 cm and number of branches of 103.6.

Cluster V with two families showed maximum average height of 114.6, diameter of 0.90 cm and number of branches of 94.9 only.

4.2.3.2. Coefficient of variability, variance, heritability and genetic advance

The genetic variance, phenotypic variance.

heritability genetic advance, genetic advance as percentage of the mean, genetic coefficient of variation and phenotypic coefficient of variation were also estimated for each of the three growth phases, in the three locations.

4.2.3.2.1. 6 months growth period

Heritability recorded for height in coastal, riverine and inland sources was 0.8138, 0.4537 and 0.6750 respectively. A similar trend was noticed for diameter at collar that showed values of 0.6159, 0.3750 and 0.8947 for the three locations respectively. The heritability values for the number of branches per plant were 0.4949, 0.7259 and 0.8536 respectively for the three sources.

Genetic advance values are presented as percentages. For height, coastal samples showed maximum value of 34.47, followed by inland samples with 27.92 and riverine 11.44. Similarly for diameter, inland sources showed promise with 34.84 per cent, followed by coastal and riverine areas. With regard to number of branches, inland families showed higher values at 22.9 followed by riverine (16.04) and coastal families (9.91).

Genotypic coefficient of variation (GCV) for height was 18.55 for coastal samples, followed by inland at

16.50 and riverine at 8.24. The same trend was seen for diameter at collar with high values for coastal samples (18.25), inland (17.00) and low values for riverine families (8.74). The phenotypic coefficient of variation (PCV) for height and diameter showed almost parallel values. The values for height were 20.56 for coastal, 20.08 for inland and 12.24 for riverine families. The same order was seen for diameter recording 23.26 for coastal 18.90 for inland and 14.27 for riverine families. The number of branches per plant showed a high GCV value for inland families (23.96) followed by coast and riverine families that were almost identical. But, PCV values ranged from 25.94 for inland, 21.31 for coastal and 15.45 for riverine families (Table 20).

4.2.3.2.2. 9 months stage

Heritability values were high for height. Coastal samples showed 0.8124, followed by inland (0.7683) and riverine sources (0.4526). A similar trend was noticed for the diameter at collar. With regard to the number of branches, heritability was low for coastal (0.4041), but increased in riverine (0.6683) and inland sources (0.8228).

Genetic advance as per cent of mean showed high values for coastal families for height (31.41), followed by inland families (29.16) and very poor for riverine (9.95)

Table 20. Genotypic and phenotypic variances, genotypic and phenotypic coefficient of variability, heritability and genetic advance

	Height			Diameter			Branches		
	Coastal	River- ine	Inland	Coastal	River- ine	Inland	Coastal	River- ine	Inland
a) 6 months									
σ^2_G	114.62	40.10	80.37	0.0085	0.0033	0.0085	46.82	83.32	145.51
σ^2_P	140.83	88.37	119.05	0.0138	0.0088	0.0095	94.60	115.19	170.45
GCV	18.55	8.24	16.50	18.25	8.74	17.00	14.99	13.13	23.96
PCV	20.56	12.24	20.08	23.26	14.27	18.90	21.31	15.45	25.94
H	0.8138	0.4537	0.6750	0.6159	0.3750	0.8947	0.4949	0.7259	0.8536
GA	19.89	8.78	15.17	0.1490	0.0724	0.1796	9.91	16.04	22.9
GA % $\bar{x}$	34.47	11.44	27.92	29.51	11.01	34.84	21.73	22.09	45.6
b) 9 months									
σ^2_G	191.2	41.11	148.16	0.0149	0.0046	0.0083	54.59	97.91	261.06
σ^2_P	235.3	90.82	192.83	0.0170	0.134	0.0105	135.09	146.49	295.70
GCV	16.94	6.48	16.15	18.77	8.21	13.92	9.99	9.92	19.91
PCV	18.77	9.64	18.42	20.09	13.98	15.66	15.66	12.72	21.19
H	0.8124	0.4526	0.7683	0.8723	0.3454	0.7904	0.4041	0.6683	0.8228
GA	25.67	8.88	21.97	0.2348	0.0825	0.1668	9.67	16.66	31.27
GA % $\bar{x}$	31.41	8.95	29.16	38.93	9.94	25.49	13.08	16.70	38.55
c) 12 months									
σ^2_G	117.46	87.00	134.63	0.0059	0.0054	0.0138	72.80	157.07	158.51
σ^2_P	185.87	120.65	156.38	0.0062	0.0152	0.0188	118.68	203.63	263.56
GCV	10.36	7.08	11.82	8.23	6.33	13.40	8.93	9.79	12.05
PCV	13.04	8.34	12.74	8.46	10.62	15.64	11.41	11.14	15.54
H	0.6319	0.7202	0.8609	0.9516	0.3552	0.7340	0.6134	0.7713	0.6014
GA	17.74	16.29	22.17	0.1543	0.0902	0.2073	13.7697	22.67	20.11
GA % $\bar{x}$	16.97	12.37	22.60	16.58	7.77	23.64	14.41	17.71	19.25

1. Genotypic variance
2. Phenotypic variance
3. Genotypic cv
4. Phenotypic cv
5. Heritability
6. Genetic Advance (GA)
7. GA as % of mean

families. The same trend was reflected with respect to diameter of stem at collar also. With regard to number of branches, the inland families showed high values (38.55) with riverine and coastal families following with lower values of 16.70 and 13.08 respectively.

Genotypic coefficient of variability for height was almost equal at 16.94 and 16.15 in coastal and inland families while it was low at 6.48 for riverine. Coastal families showed slightly increased values (18.77) for diameter at collar, followed by inland at 13.92 and riverine families at 8.21. A similar trend was also reflected in phenotypic coefficient of variation for height and diameter. With regard to number of branches, inland families showed high values (21.19) followed by coastal (15.66) and riverine (12.72) families (Table 20).

4.2.3.2.3. 12 months stage

Heritability values were consistently high for height among the three sources of collection. Coastal families indicated 0.6319 while the inland and riverine sources showed 0.8609 and 0.7202 respectively. Similar trend but reduced value (0.3552) was seen for riverine samples in the case of diameter at collar. With regard to number of branches, heritability was high at 0.6134 for coast, 0.7713 for riverine

and 0.6014 for inland families.

Genetic advance as per cent of mean reflected the above trend for height; coastal families showed 16.97, inland 22.60 and riverine 12.37. The diameter at collar showed 23.64 for inland families, coastal families 16.58 and riverine families registered 7.77. With regard to number of branches, inland samples showed the high value of 19.25, followed by riverine (17.71) and coastal families (14.41).

Genotypic coefficient of variability for height was 11.82 for inland, 10.36 for coast and 7.08 for riverine families. For diameter at collar, inland samples showed the high value of 13.40, followed by coast and riverine families 8.23 and 6.33 respectively. The same trend was reflected in the case of number of branches per family. The genotypic coefficient of variability was low for coast (8.93) and riverine (9.79) and moderate (12.05) for inland families. Phenotypic coefficient of variability followed the same trend and recorded 11.41, 11.14 and 15.54 for coastal, riverine and inland families respectively (Table 20).

4.3. BIOMASS

Casuarina equisetifolia was raised in three different centres representing coastal, riverine and inland

areas. In each centre, the growth of the plant was monitored by measuring the increments in height, diameter at collar (base) and diameter at breast height. Dry weight of stem, bark, branches, needle and roots was assessed separately and per cent distribution or partitioning of stem, bark, branches, needle and root to the total weight was calculated. Measurements and recordings were done for three stages of growth viz., one, three and six years after sowing.

4.3.1. Growth over years

4.3.1.1. First year

4.3.1.1.1. Coastal plantations (Marakkanam)

The plants showed a maximum growth of 144.0 cm and a minimum of 65.0 cm with a mean of 108.58 cm (cv 19.24). The diameter at collar ranged from 0.52 to 1.25 cm with a mean of 0.88 cm (cv 20.04). The weight of stem varied from 31.0 to 85.0 g with an average of 51.53 g and a cv of 26.70. The needle weight ranged from 8.0 to 20.0 g with an average of 12.81 g (cv 25.83). Root weight showed a minimum of 8.0 g to a maximum of 17.5 g with a mean of 11.65 g (cv 23.0). The total weight of the plant ranged from 48.0 to 118.5 g with a mean of 75.3 g and a cv of 25.63. The stem formed 68.54 per cent to the total weight while the needle and root shared 16.84 and 15.22 per cent of the biomass. These three characters showed low cv values (The weight of bark and branch

was not recorded at this stage of growth of one year after soing)(Table 21; Fig.18).

4.3.1.1.2. Riverine plantation (Natham)

The height of the plant ranged from 95 to 200 cm with a mean of 150.4 cm (cv 21.42). The diameter at collar registered 0.7 to 1.75 cm and averaged 1.23 cm with a cv of 23.12. The stem weight ranged from 40.0 to 125.0 g with an average of 83.95 g and (cv 28.21). The needle weight ranged from 9.0 to 32.0 g and showed a mean of 20.21 g with cv of 30.21. The root weight ranged from 8.0 to 29.0 g with a mean of 17.37 g (cv 32.23). The total weight of the plants ranged from 57.0 to 186.0 g with a mean of 121.62 g and a cv of 28.33. The percentage of stem, needle and root to the total weight was 69.11, 16.38 and 13.71 respectively (Table 22; Fig.18).

4.3.1.1.3. Inland plantation (Virudhachalam)

The height of the individual plants ranged from 39.0 to 113.0 cm with an average of 79.37 cm (cv 24.89). The diameter at collar ranged from 0.35 to 1.10 cm with an average of 0.69 cm and cv of 27.88. The stem weight of plant ranged from 22.1 to 87.5 g with a mean of 44.5 (cv 34.15). The needle weight ranged from 5.7 to 17.5 g with a mean of 10.84 g (cv 27.21) and the root weight ranged from 6.3 to 15.4 g with

Table 21. Components of biomass in coastal centre - Marakkanam - I Year

S. No.	Height cm	dia at collar cm	Stem weight g	Needle weight g	Root weight g	Total weight g	% Stem	% Needle	% Root
1.	119.5	1.21	57.0	17.0	13.0	87.0	65.51	19.54	14.94
2.	144.0	1.10	62.0	12.0	11.0	85.0	72.94	14.11	12.94
3.	107.0	0.93	53.5	13.0	12.0	78.5	68.15	16.56	15.28
4.	84.6	0.79	46.5	12.0	13.0	71.5	65.03	16.78	18.18
5.	121.0	0.81	59.0	13.0	12.0	84.0	70.23	15.47	14.28
6.	130.0	0.85	59.0	16.0	15.0	90.0	65.55	17.77	16.66
7.	119.0	0.91	52.0	13.0	14.0	79.0	65.82	16.45	17.72
8.	107.5	0.85	46.0	14.0	10.0	70.0	65.71	20.00	14.28
9.	99.0	0.60	35.0	9.0	8.0	52.0	67.96	17.47	14.56
10.	95.0	0.72	40.5	10.5	8.0	59.0	68.64	17.79	13.55
11.	117.0	0.93	44.0	10.0	9.0	63.0	69.84	15.87	14.28
12.	128.0	0.86	42.0	11.0	10.5	63.5	66.14	17.32	16.66
13.	127.0	1.10	81.0	20.0	17.5	118.5	68.35	16.87	14.76
14.	137.0	1.25	85.0	17.0	16.0	118.0	72.03	14.40	13.55
15.	65.0	0.52	31.0	8.0	9.0	48.0	64.58	16.66	18.75
16.	112.0	1.00	59.5	18.5	14.5	87.5	69.00	15.42	16.57
17.	86.5	0.72	42.0	11.5	9.8	63.3	66.35	18.16	15.48
18.	107.0	0.90	50.0	10.2	9.5	69.7	71.73	14.63	13.62
19.	79.5	0.85	47.0	9.5	10.7	67.2	69.94	14.13	15.92
20.	86.0	0.94	39.5	11.0	10.5	51.5	77.45	21.56	13.55
Mean	108.58	0.88	51.53	12.81	11.65	75.31	68.54	16.84	15.22
cv %	19.24	20.04	26.70	25.83	23.00	25.63	4.72	11.69	10.97

Table 22. Components of biomass in riverine centre - Natham - I Year

S. No.	Height cm	dia at collar cm	Stem weight g	Needle weight g	Root weight g	Total weight g	% Stem	% Needle	% Root
1.	110.5	0.86	49.5	17.0	13.0	79.5	62.26	21.38	16.35
2.	150.0	1.26	83.0	23.0	19.0	125.0	66.40	18.40	15.20
3.	140.5	0.97	71.0	17.0	15.0	103.0	68.93	16.50	14.56
4.	190.0	1.52	92.0	16.0	18.0	126.0	73.01	12.69	14.28
5.	200.0	1.75	104.0	29.0	26.0	159.0	65.40	18.23	16.35
6.	180.0	1.45	107.0	24.0	23.0	154.0	69.48	15.58	14.93
7.	195.0	1.54	125.0	32.0	29.0	186.0	67.20	17.20	15.59
8.	151.0	0.97	67.0	18.0	12.0	97.0	69.07	18.55	12.37
9.	149.0	0.95	66.0	13.0	13.0	92.0	71.73	14.13	14.13
10.	140.0	1.15	93.0	22.0	24.0	147.0	63.26	14.96	16.32
11.	150.5	1.27	99.0	27.0	17.0	143.0	69.23	18.88	11.88
12.	175.0	1.55	122.0	25.0	28.0	165.0	73.93	15.15	10.90
13.	120.0	1.10	76.5	21.0	18.0	115.5	66.23	18.18	15.58
14.	166.5	1.45	95.0	24.0	19.0	138.0	68.84	17.39	13.76
15.	150.0	1.24	61.5	10.5	11.0	83.0	74.09	12.65	13.25
16.	95.0	0.70	40.0	9.0	8.0	57.0	70.17	15.78	14.03
17.	179.0	1.67	95.0	21.0	19.0	135.0	70.37	15.55	14.07
18.	165.0	1.37	113.0	23.0	24.0	160.0	70.71	14.33	14.95
19.	91.0	1.03	57.0	12.5	11.0	80.5	70.80	15.52	13.66
20.	110.0	0.95	62.0	14.5	10.5	87.0	71.26	16.66	12.06
Mean	150.4	1.23	83.95	20.21	17.37	121.62	69.11	16.38	13.71
cv%	20.42	23.12	28.21	30.21	32.23	28.33	4.54	13.03	16.11

a mean of 9.98 g (cv 21.74). The total weight of the plant ranged from 34.1 to 120.4 g with a mean of 65.41 g and a cv of 29.62 (Table 23; Fig.18).

4.3.1.1.4. Correlation values

4.3.1.1.4.1. Coastal plantation

Total weight of the plant was regressed against variables like plant height, diameter at collar, stem weight, needle weight, root weight, per cent of stem, per cent of needle and per cent of root. All the measurable traits gave highly positive and significant correlation. Percentage of stem, per cent to total dry weight showed feeble correlation while that of needle and root showed negative but non-significant correlation values (Table 24).

4.3.1.1.4.2. Riverine plantation

In this case also, total weight of stem was regressed against eight variables. All the measurable characters showed positive correlation of above 0.80 excepting stem needle and root per cent to the total weight which showed negative correlation (Table 24).

4.3.1.1.4.3. Inland plantation

The two variables that showed negative correlation

Table 23. Components of biomass in inland centre - Virudhachalam - I Year

S. No.	Height cm	dia at collar cm	Stem weight g	Needle weight g	Root weight g	Total weight g	% Stem	% Needle	% Root
1.	82.5	0.75	45.7	10.5	9.7	65.9	69.34	15.93	14.71
2.	113.0	0.95	67.5	13.7	12.5	93.7	72.03	14.62	13.34
3.	68.0	0.50	39.4	6.0	8.0	53.4	73.78	11.23	14.98
4.	111.0	0.85	55.0	13.0	10.5	78.5	70.06	16.56	13.37
5.	78.0	0.65	39.4	11.0	13.5	63.9	61.65	17.21	21.12
6.	85.0	0.72	42.3	9.0	10.7	62.0	68.22	14.51	17.25
7.	68.0	0.49	27.4	8.5	9.2	45.1	60.75	18.18	20.39
8.	57.0	0.51	25.2	7.8	8.2	41.2	61.16	18.93	19.90
9.	78.0	0.82	47.1	13.0	10.1	70.1	67.18	18.54	14.40
10.	49.0	0.45	30.5	10.5	8.2	49.2	61.99	16.93	16.66
11.	39.0	0.35	22.1	5.7	6.3	34.1	64.80	16.71	18.47
12.	59.0	0.48	42.4	7.0	8.8	58.2	72.85	12.02	15.12
13.	80.0	0.68	47.5	11.0	7.8	66.3	71.64	16.59	11.76
14.	69.0	0.61	35.0	14.0	9.2	58.2	60.13	24.05	15.80
15.	78.0	0.72	39.2	11.0	8.9	59.1	66.32	18.61	15.05
16.	85.0	0.75	37.3	10.8	10.4	58.5	63.76	16.93	17.77
17.	94.0	0.88	48.0	10.7	8.7	67.4	71.21	15.87	12.90
18.	107.0	1.05	87.5	17.5	15.4	120.4	72.67	14.53	12.79
19.	95.0	1.00	57.6	13.5	12.0	83.1	69.31	16.24	17.31
20.	92.0	1.10	55.8	12.7	11.5	80.0	69.75	15.87	14.37
Mean	79.37	0.69	44.5	10.84	9.98	65.41	67.38	16.46	15.83
cv %	24.89	27.88	34.15	27.21	21.74	29.62	6.56	15.78	16.35

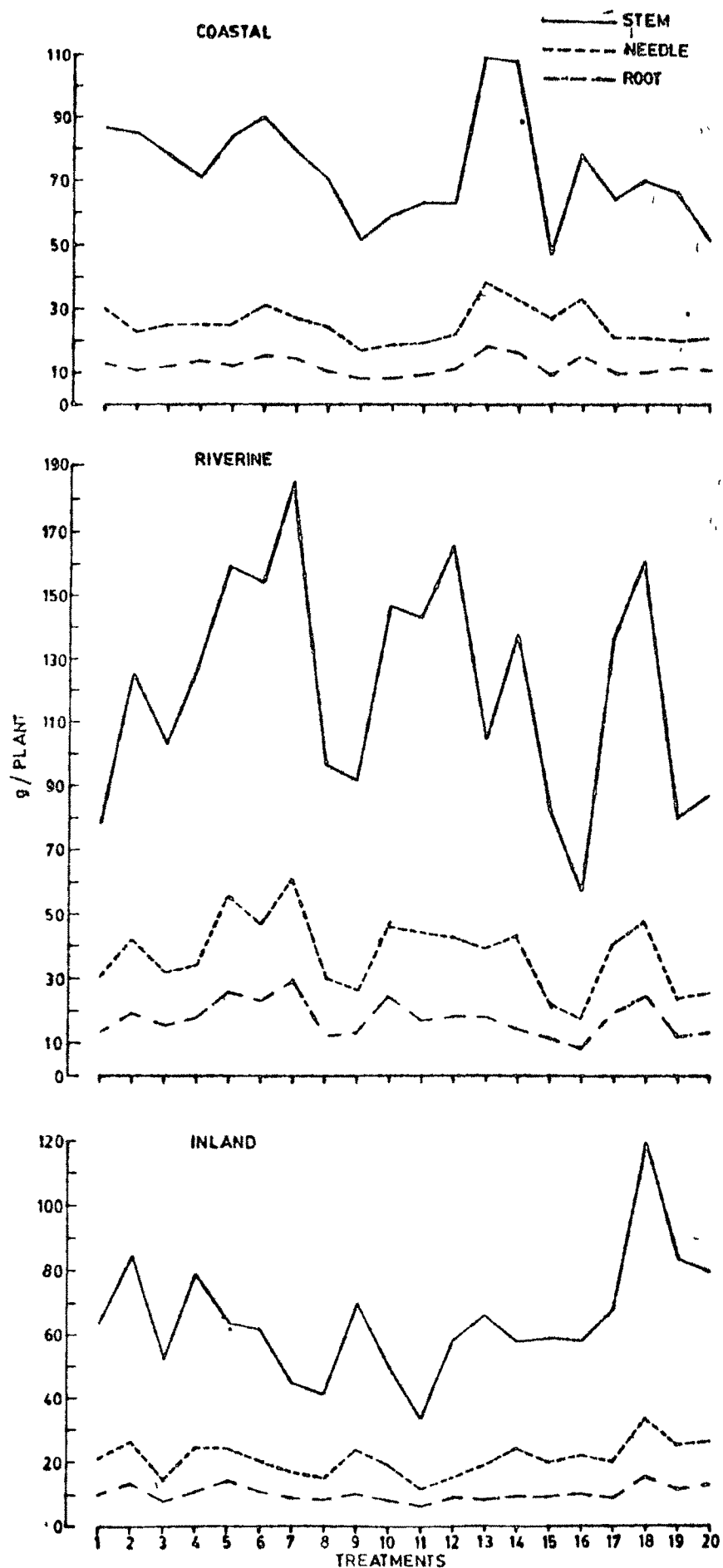


FIG 18 PARTITIONING OF BIOMASS COMPONENTS IN FIRST YEAR

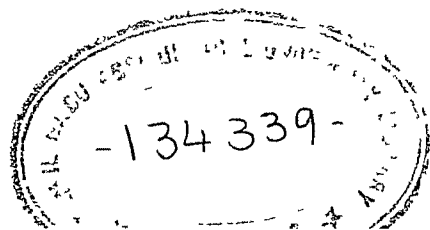
Table 24. Correlation values for plant characters with biomass (Yield) - I Year
(Three centres)

Character	Total yield	Plant height	Dia at collar	Stem weight	Needle weight	Root weight	% Stem	% Needle	% Root
<u>1 Year - Coastal plantation</u>									
1.Total yield		0.7075**	0.7591**	0.9866**	0.8716**	0.8932**	0.0543	-0.3347	-0.1560
2.Plant height			0.6951**	0.7111**	0.5824**	0.5206*	0.1412	-0.2588	-0.3752
3.Diameter at collar				0.7920**	0.6987**	0.6537**	0.3809	-0.1592	-0.3875
4.Stem weight					0.8243**	0.8541**	0.2085	-0.3747	-0.2776
5.Needle weight						0.8778**	0.0693	0.0386	-0.0604
6.Root weight							0.0583	-0.1622	0.1788
7.Stem %								0.1274	-0.7004**
8.Needle %									-0.2094
9.Root %									-
<u>1 Year - Riverine plantation</u>									
1.Total yield		0.8031**	0.8210**	0.9866**	0.9195**	0.9636**	-0.1262	-0.0153	0.1528
2.Plant height			0.8813**	0.8244**	0.6773**	0.7505**	0.1232	-0.2005	0.0934
3.Diameter at collar				0.8447**	0.7059**	0.7845**	0.1285	-0.1754	0.0559
4.Stem weight					0.8683**	0.9394**	0.0300	-0.1131	0.0402
5.Needle weight						0.8762**	-0.3748	0.3660	0.2128
6.Root weight							-0.2067	-0.0153	0.2853
7.Stem %								-0.7159**	0.7322**
8.Needle %									0.1963
9.Root %									-

/Contd./

Table 24.(Contd)

Character	Total yield	Plant height	Dia at collar	Stem weight	Needle weight	Root weight	% Stem	% Needle	% Root
<u>1 Year - Inland plantation</u>									
1.Total yield		0.8528**	0.8435**	0.9902**	0.8422**	0.8343**	0.5757**	-0.2474	-0.5364**
2.Plant height			0.8775**	0.8404**	0.7304**	0.7231**	0.5155*	-0.1779	-0.5353*
3.Diameter at collar				0.8126**	0.7972**	0.7210**	0.4257	-0.0476	-0.4736*
4.Stem weight					0.7723**	0.7749**	0.6782**	-0.3511	-0.6485**
5.Needle weight						0.7417**	0.1370	0.2829	0.4443*
6.Root weight							0.1937	-0.1280	-0.0793
7.Stem %								-0.7647	-0.7686
8.Needle %									0.2757
9.Root %									-



with total yield were per cent needle to stem and per cent root to the stem.

Per cent stem to the total weight showed significant correlation value (Table 24).

4.3.1.2. Third year

4.3.1.2.1. Coastal plantation (Marakkanam)

The maximum growth recorded for height was 5.62 m and a minimum of 1.90 m with a mean of 3.71 m and cv of 28.66. The diameter growth at collar was 1.90 to 4.00 cm with a mean of 2.91 cm (cv of 19.9). The diameter at breast height of ranged from a minimum of 1.2 to a maximum of 3.0 cm with a mean of 1.99 cm (cv 26.06). The stem weight was from 0.7 to 3.7 kg with a mean of 2.33 kg (cv 36.7). The branches showed a weight range of 0.5 to 1.2 kg with a mean of 0.83 (cv 26.9). The needle recorded a range of 0.60 to 1.90 kg and a mean of 1.12 kg (cv 35.00). The roots recorded an average weight of 0.78 kg (range 0.4 to 1.7) and a cv of 41.7. The weight of the whole plant recorded was 2.5 (minimum) and 8.30 kg (maximum) and a mean of 5.06 kg (cv 34.1).

The per cent of stem height to total plant weight was in the range of 28.0 to 51.1 with a mean of 45.4 (cv 10.55).

Similarly the per cent (ratio) of needle to whole plant recorded was 17.9 to 32.0 per cent with a mean of 22.4 (cv 12.9). The weight of root ranged from 12.2 to 20.5 per cent with a mean of 15.4 and cv of 14.7 (Table 25; Fig.19).

4.3.1.2.2. Riverine plantation (Natham)

The maximum height growth reported for this plantation was 7.63 m and the lowest was 2.90 m with a mean of 6.0 m (cv 24.2). The diameter at collar ranged from 3.10 to 7.00 cm with a mean of 4.94 cm (cv 25.9). The diameter at breast height varied from a low of 2.4 to a high of 5.5 cm with an average of 3.8 cm (cv 29.97). The stem weight ranged from a minimum of 2.2 to 7.5 kg with a mean of 4.8 kg and cv of 30.9. The branches weighed from 0.7 to 2.0 kg with a mean of 1.3 kg (cv 29.1). The needle contributed 0.9 to 2.2 kg with a mean of 1.6 kg and cv of 22.9. The root contributed from 0.9 to 2.7 kg with an average of 1.8 kg and a cv of 24.9. The total weight of the plant ranged from 4.7 to 14.2 kg with a mean of 9.6 kg (cv 26.9).

The stem, branch, leaf and root showed an average of 49.9, 13.9, 17.3 and 18.7 per cent to the total weight. The coefficient of variation was 6.6, 12.2, 12.4 and 9.5 respectively (Table 26; Fig.19).

Table 25. Components of biomass in coastal centre - Marakkanam - III Year

Sl. No.	Height cm	Dia at collar cm	Dia at bh cm	Stem weight kg	Branch weight kg	Needle weight kg	Root weight kg	Total weight kg	% Stem	% Branch	% Needle	% Root
1.	562	4.0	2.5	3.7	1.2	1.6	0.9	7.4	50.0	16.2	21.6	12.2
2.	365	2.5	1.7	1.8	0.8	0.7	0.6	3.9	46.2	20.5	17.9	15.4
3.	515	3.5	2.2	3.5	1.1	1.9	1.2	7.7	45.5	14.3	24.7	15.6
4.	375	2.6	1.5	1.9	0.7	0.9	0.6	4.1	46.3	17.1	21.9	14.6
5.	405	2.8	1.5	2.7	1.0	1.3	0.9	5.9	45.7	17.0	22.0	15.3
6.	515	3.5	2.2	3.3	1.2	1.4	0.9	6.8	48.5	17.6	20.6	13.2
7.	370	2.6	1.9	2.2	0.7	0.9	0.6	4.4	50.0	15.9	20.5	13.6
8.	425	3.7	2.9	3.4	1.1	1.7	1.2	7.4	45.9	14.9	23.0	16.2
9.	390	2.9	1.9	2.5	0.9	1.2	1.1	5.7	43.9	15.8	21.0	19.3
10.	265	2.5	1.6	2.1	0.6	0.9	0.8	4.3	48.8	13.9	20.9	18.6
11.	317	2.9	2.5	2.2	0.7	0.9	0.6	4.3	51.1	16.3	20.9	17.6
12.	250	2.4	1.7	1.9	0.6	0.9	0.6	4.0	47.5	15.0	22.5	14.0
13.	310	2.9	2.5	2.4	0.8	1.0	0.8	5.0	48.0	16.0	20.0	16.0
14.	310	2.5	1.9	1.2	0.7	0.7	0.4	3.0	40.0	23.3	23.3	13.3
15.	480	3.9	2.7	3.1	0.9	1.6	0.9	6.5	47.6	13.8	24.6	13.9
16.	560	3.7	3.0	3.6	1.2	1.8	1.7	8.3	43.4	14.4	21.7	20.5
17.	290	2.6	1.6	1.9	0.7	0.9	0.6	4.1	46.3	17.1	21.9	14.6
18.	290	2.4	1.4	1.3	0.6	0.6	0.5	3.0	43.3	20.0	20.0	16.7
19.	205	1.9	1.2	0.7	0.6	0.8	0.4	2.5	28.8	24.0	32.0	16.0
20.	235	2.4	1.5	1.3	0.5	0.8	0.4	3.0	43.3	16.7	26.7	13.3
Mean	371.7	2.91	1.99	2.33	0.83	1.12	0.78	5.06	45.4	17.0	22.4	15.4
cv %	28.6	19.9	26.0	36.7	26.9	35.0	41.7	34.1	10.55	16.5	12.9	14.7

Dia bh: Diameter at breast height

Table 26. Components of biomass in riverine centre - Natham - III Year

Sl. No.	Height	Dia at collar	Dia at bh	Stem weight	Branch weight	Needle weight	Root weight	Total weight	% Stem	% Branch	% Needle	% Root
cm	cm	cm	cm	kg	kg	kg	kg	kg				
1.	625	4.9	4.1	4.3	1.0	1.9	1.7	8.9	48.3	11.2	21.3	19.1
2.	680	5.8	4.4	5.2	1.3	1.6	1.3	10.0	52.0	13.0	16.0	19.0
3.	702	6.6	5.5	6.0	1.8	2.1	2.3	12.2	49.2	14.7	17.2	18.9
4.	763	7.0	5.2	7.0	1.8	2.0	2.7	13.5	51.8	13.3	14.8	20.1
5.	760	6.6	5.6	7.5	2.0	2.2	2.5	14.2	52.8	14.1	15.5	17.6
6.	763	5.7	4.7	6.5	2.0	2.2	2.3	13.0	50.0	15.4	16.9	17.7
7.	701	5.5	3.5	4.5	1.8	1.9	1.8	10.0	45.0	18.0	19.0	18.0
8.	718	5.2	3.5	5.7	1.3	1.8	1.7	10.5	54.3	12.4	17.1	16.2
9.	376	3.5	2.8	2.7	0.9	1.1	1.4	6.1	44.2	14.8	18.0	22.9
10.	701	4.8	3.6	5.0	1.4	2.0	1.9	10.3	48.5	13.6	19.4	18.4
11.	550	3.4	2.5	4.0	1.2	1.4	1.9	8.5	47.0	14.1	16.5	22.4
12.	435	3.6	2.4	3.5	1.3	1.2	1.4	7.4	47.3	17.6	16.2	18.9
13.	590	4.2	3.4	4.5	1.1	1.5	1.6	8.7	51.7	12.6	17.2	18.4
14.	706	6.9	5.7	6.5	1.8	1.5	1.9	11.7	55.5	15.4	12.8	16.2
15.	350	3.4	2.6	2.5	0.8	1.2	1.0	5.5	45.4	14.5	21.8	18.2
16.	290	3.1	2.6	2.2	0.7	0.9	0.9	4.7	46.8	14.9	19.1	19.1
17.	475	3.9	3.0	3.8	1.0	1.4	1.3	7.5	50.8	13.3	18.6	17.3
18.	505	4.0	2.9	4.2	1.1	1.3	1.8	8.4	50.0	13.1	15.5	21.5
19.	730	6.5	5.8	6.8	1.4	1.8	2.1	12.1	56.2	11.6	14.9	17.4
20.	580	4.2	3.2	4.5	1.1	1.6	1.8	9.0	50.0	12.2	17.8	20.0
Mean	600	4.9	3.8	4.8	1.3	1.6	1.8	9.6	49.9	13.9	17.3	18.7
cv %	24.2	25.9	29.9	30.9	29.1	22.9	24.9	26.9	6.6	29.1	12.4	9.5

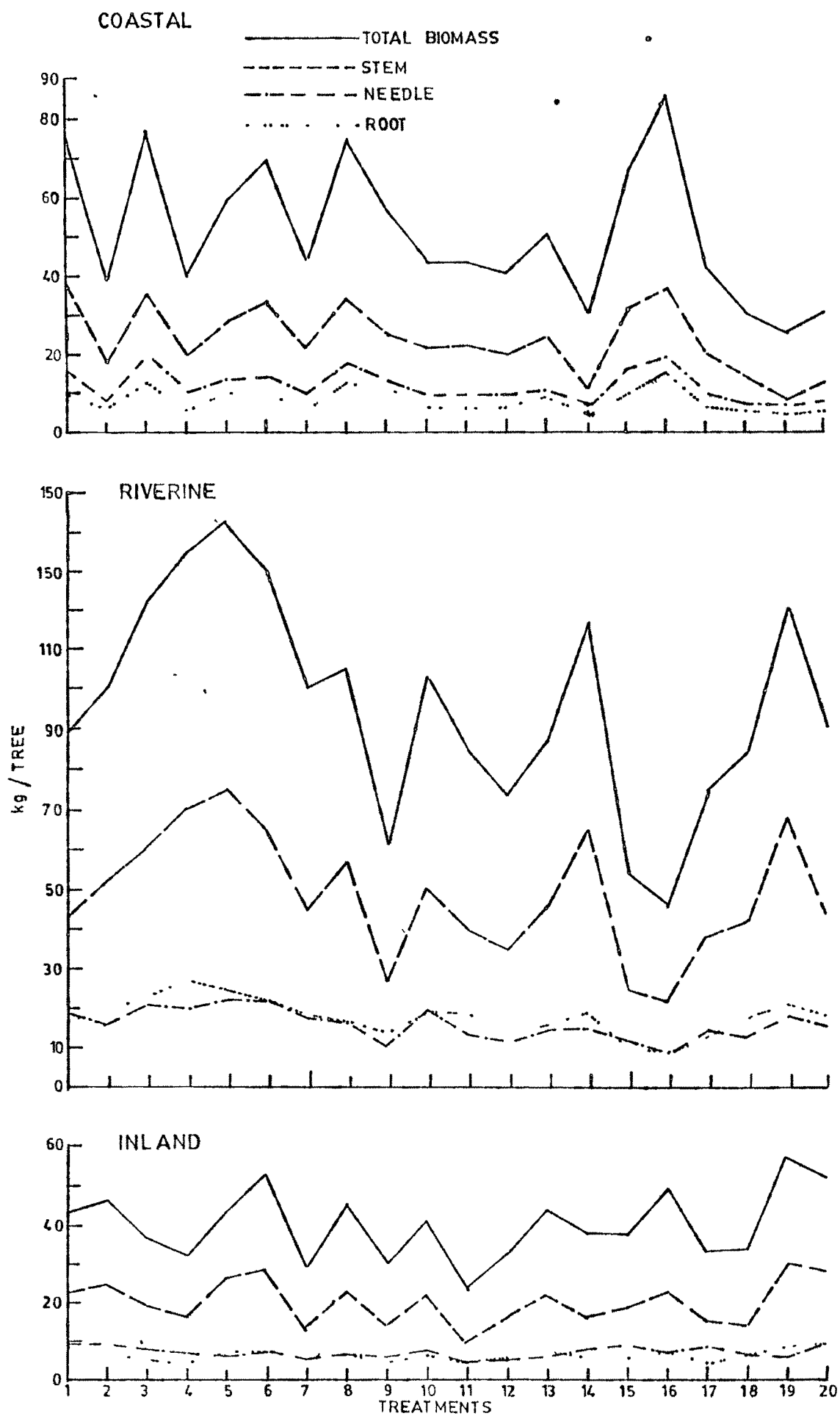


FIG 19 PARTITIONNING OF BIOMASS COMPONENTS IN THIRD YEAR

4.3.1.2.3. Inland plantation (Virudhachalam)

The plants showed a height growth ranging from 1.77 to 4.0 m with an average of 2.32 m (cv 26.7). The diameter at collar ranged from 1.8 to 3.4 cm with a mean of 2.3 cm (cv 18.3). The diameter at breast height ranged from 1.2 to 2.5 cm averaging 1.6 cm (cv 19.3). The stem weight showed a minimum of 1.0 kg to a maximum of 3.0 kg with a mean of 2.0 (cv 26.9). The branches weighed from 0.4 to 1.0 kg with a mean of 0.6 kg (cv 28.5). The weight of needle ranged from 0.5 to 1.0 kg with a mean of 0.70 kg (cv 19.3) while the root recorded a mean of 0.5 kg (cv 24.6) and with a maximum of 0.9 and a minimum of 0.4 kg. The total weight of plant ranged from a minimum of 2.4 to 5.2 kg with a mean value of 3.9 kg (cv 21.6).

The stem, branch, needle and root showed 50.2, 16.8, 18.0 and 15.0 per cent to the total weight of the plant with corresponding cv values of 8.5, 23.4, 15.4 and 12.4 respectively (Table 27; Fig 19).

4.3.1.2.4. Correlation values

4.3.1.2.4.1. Coastal plantation

Height of the plant, diameter at collar, diameter at breast height, stem weight, branch weight, needle weight and

Table 27. Components of biomass in inland centre - Virudhachalam - III Year

Sl. No.	Height cm	Dia at collar cm	Dia at bh cm	Stem wei- ght kg	Branch weight kg	Needle weight kg	Root weight kg	Total weight kg	% Stem	% Branch	% Needle	% Root
1.	265	2.6	1.8	2.2	0.4	0.9	0.8	4.3	51.2	9.3	20.9	18.6
2.	215	2.7	1.9	2.4	0.6	0.9	0.7	4.6	52.2	13.0	19.6	15.2
3.	197	2.1	1.2	1.9	0.4	0.8	0.5	3.6	52.8	11.1	22.2	13.9
4.	155	1.7	1.6	1.6	0.5	0.7	0.4	3.2	50.0	15.6	21.9	12.5
5.	214	2.5	1.5	2.6	0.4	0.6	0.7	4.3	60.5	9.3	13.9	16.3
6.	350	3.0	2.1	2.9	0.9	0.7	0.7	5.2	55.7	17.3	13.5	13.5
7.	185	2.0	1.6	1.4	0.5	0.5	0.5	2.9	48.3	17.2	17.2	17.3
8.	270	2.5	1.5	2.3	0.9	0.7	0.6	4.5	51.1	20.0	15.6	13.3
9.	195	2.0	1.3	1.4	0.6	0.6	0.4	3.0	46.7	20.0	20.0	13.3
10.	225	2.2	1.7	2.2	0.5	0.8	0.6	4.1	53.7	12.2	19.5	14.6
11.	177	2.5	1.5	1.0	0.5	0.5	0.4	2.4	41.7	20.8	20.8	16.7
12.	175	2.0	1.4	1.6	0.6	0.6	0.5	3.3	48.5	18.2	18.2	15.2
13.	220	2.5	1.6	2.2	0.8	0.7	0.7	4.4	50.0	18.2	15.9	15.9
14.	240	2.1	1.7	1.7	0.9	0.6	0.5	3.7	45.9	24.3	16.2	13.5
15.	210	2.2	1.4	1.9	0.7	0.6	0.5	3.7	51.3	18.9	16.2	13.5
16.	275	2.5	1.9	2.3	0.9	1.0	0.7	4.9	46.9	18.4	20.4	14.3
17.	190	2.2	1.6	1.6	0.7	0.6	0.4	3.3	48.5	21.2	18.2	12.1
18.	175	1.8	1.6	1.4	0.6	0.7	0.6	3.3	42.4	18.2	21.2	18.2
19.	400	3.4	2.5	3.0	3.0	0.9	0.8	5.7	52.6	17.5	15.8	14.0
20.	320	3.2	2.4	2.8	0.8	0.7	0.9	5.2	53.8	15.4	13.5	17.3
Mean	232.6	2.38	1.69	2.0	0.6	0.7	0.5	3.98	50.2	16.8	18.0	15.0
cv %	26.7	18.3	19.3	26.9	28.5	19.3	24.6	21.6	8.5	23.4	15.4	12.4

root weight showed highly significant correlation with total weight of the tree. Per cent stem weight showed positive correlation (0.3705) but was non-significant. The same showed positive significant correlation with diameter at collar, and stem weight. The correlation for other characters based on per cent was negligible or non existent (Table 28).

4.3.1.2.4.2. Riverine plantation

Tree height, diameter at collar, diameter at breast height, stem weight, branch weight, needle weight, root weight and per cent stem showed highly significant positive correlation values with total weight of the plant. Per cent root exhibited significant positive correlation at 0.05 level. Per cent stem showed highly significant correlation with plant height, diameter at collar, diameter at breast height and stem weight. It showed significant correlation with its root weight. Per cent branch showed negligible correlation for all characters except per cent stem to which it showed significant negative correlation. Per cent needle did not exhibit any positive association. Per cent root showed negative correlation for all traits except total weight (Table 29).

4.3.1.2.4.3. Inland plantation

Eight characters as seen in riverine plantation showed positive correlation with total weight of the tree.

Table 28. Correlation values for plant characters with biomass - Coastal centre - III Year

S. No.	Character	Total weight	Plant height	Dia at collar	bh	Dia at Stem	Branch weight	Needle weight	Root weight	% Stem	% Branch	% Needle	% Root
1.	Total weight	0.9112*	0.9246**	0.7741*	0.9822*	0.9352*	0.9585*	0.9121*	0.3785	-0.6344**	-0.1835	0.1566	
2.	Plant height		0.9022*	0.6856*	0.9030*	0.9322*	0.8333*	0.7683*	0.3649	-0.4259	-0.2557	-0.0086	
3.	Dia at collar			0.8594**	0.9383*	0.8687*	0.8772*	0.7551**	0.4480*	-0.5797**	-0.1813	-0.0172	
4.	Dia at bh				0.7856*	0.6885*	0.6984**	0.7055*	0.4074	-0.5259*	-0.2134	0.1740	
5.	Stem weight					0.9064**	0.9229*	0.8497*	0.5321*	-0.6952*	-0.2894	0.0896	
6.	Branch weight						0.8563*	0.8125*	0.2469	-0.3465	-0.1953	0.0586	
7.	Needle weight							0.8692*	0.2449	-0.6452*	-0.0518	0.1481	
8.	Root weight								0.2143	-0.6122	-0.1828	0.5124*	
9.	Stem %									-0.6975**	-0.7498*	-0.1249	
10.	Branch %										0.2886	-0.2165	
11.	Needle %											-0.1488	
12.	Root %												

Table 29. Correlation values for plant characters with biomass - Riverine centre - III Year

S. No.	Character	Total Tree weight	Tree height	Dia at collar	Dia at bh	Stem weight	Branch weight	Needle weight	Root weight	% Stem	% Branch	% Needle	% Root
1.	Total weight	0.9471*	0.9176*	0.8716*	0.9845*	0.9064*	0.8871*	0.9449*	0.6371*	-0.0743	-0.5596*	0.4807*	
2.	Tree height		0.8768*	0.7934*	0.9275*	0.8336*	0.9103*	0.8751*	0.6196*	-0.1536	-0.4425	-0.5022*	
3.	Dia at collar			0.9574*	0.9246*	0.8368*	0.7752*	0.8242*	0.6544*	-0.0428	-0.5357	-0.5796*	
4.	Dia at bh				0.8969*	0.7503*	0.7179*	0.7746*	0.6825*	-0.1545	-0.5239*	-0.5269*	
5.	Stem weight					0.8525*	0.8244*	0.9034*	0.7569*	-0.1590	-0.6275*	-0.5390*	
6.	Branch weight						0.7953*	0.8421*	0.3915	0.3430	-0.5334*	-0.4525*	
7.	Needle weight							0.8332*	0.3808	-0.1256	-0.1361	-0.4479*	
8.	Root weight								0.4838*	-0.0909	-0.5497*	-0.2017	
9.	Stem %									-0.4726*	-0.6767*	-0.6072*	
10.	Branch %										-0.0666	-0.0146	
11.	Needle %											0.1436	
12.	Root %											-	

Per cent branch, per cent needle and per cent root showed negative correlation with per cent needle showing significant values. Per cent stem showed significantly positive correlation with diameter at collar, stem weight and root weight. Per cent branch did show non-significant positive correlation with stem weight, but other traits were negatively correlated. Per cent needle showed negative correlation with all other characters. Per cent root showed positive correlation with root weight and negative correlation with all other characters (Table 30).

4.3.1.3. Sixth year

4.3.1.3.1. Coastal plantation

The height of the trees ranged from 6.0 to 14.0 m with an average of 11.1 m (cv 20.0). The diameter at collar ranged from 6.0 to 15.5 cm with a mean of 11.5 (cv 20.0). The diameter at breast height ranged from 4.6 to 12.7 cm with a mean of 8.2 cm (cv 22.9). The stem weight recorded a minimum of 7.00 kg to a maximum of 56.0 kg while the mean was 30.6 kg with a cv of 38.9. The bark weight ranged from 0.8 to 4.9 kg with a mean of 2.8 (cv 37.4). The branch weight ranged from 2.1 to 12.7 kg averaging 5.6 kg with a cv of 41.4. The needle weight recorded a range of 2.2 to 18.0 kg with a mean of 9.97 kg with a cv of 38.54. The root weight ranged from 1.8 to 14.0 kg averaging 8.0 kg with a cv of 38.4. The total weight

Table 30. Correlation values for plant characters with biomass - Inland centre - III Year

i.	Character	Total Tree weight	Dia at collar	bh	Dia at Stem	Stem weight	Branch weight	Needle weight	Root weight	% Stem	% Branch	% Needle	% Root
1.	Total weight	0.8832 ^{**}	0.8213 ^{**}	0.7756 ^{**}	0.9693 ^{**}	0.5922 ^{**}	0.6733 ^{**}	0.8732 ^{**}	0.6054 ^{**}	-0.2699	-0.5359 [*]	-0.0277	
2.	Tree height		0.8780 ^{**}	0.8304 ^{**}	0.8357 ^{**}	0.6820 ^{**}	0.4878 [*]	0.7423 ^{**}	0.4164	-0.0376	-0.5629 ^{**}	-0.0480	
3.	Dia at collar			0.8087 ^{**}	0.8094 ^{**}	0.5044 [*]	0.4060 [*]	0.7810 ^{**}	0.4529 [*]	-0.1575	-0.5661 [*]	-0.1298	
4.	Dia at bh				0.7087 ^{**}	0.5624 ^{**}	0.4736 [*]	0.7503 ^{**}	0.2647	-0.0575	-0.4269	0.1415	
5.	Stem weight					0.4518 [*]	0.5795 [*]	0.8470 ^{**}	0.7762 ^{**}	0.4063	-0.5994 [*]	-0.0357	
6.	Branch weight						0.2033	0.3191	-0.0521	-0.6106 [*]	-0.5404 [*]	-0.3772	
7.	Needle weight							0.6037 ^{**}	0.2376	-0.4355	0.2492	0.0027	
8.	Root weight								0.5100 [*]	-0.4515 [*]	-0.4504 [*]	0.4521 [*]	
9.	Stem %									-0.6628 ^{**}	-0.5513 [*]	-0.1042	
10.	Branch %										-0.1432	-0.3855	
11.	Needle %											0.0409	
12.	Root %												-

of the individual tree ranged from a minimum of 13.9 kg to a maximum of 105.6 kg with a mean of 57.0 kg (cv 38.0) (Table 31; Fig.20).

The mean per cent apportioning of the major components of the tree was as follows:

Stem	53.3 (cv 5.3)
Bark	5.0 (cv 12.0)
Branches	10.3 (cv 23.9)
Needle	16.9 (cv 13.8)
Root	14.1 (cv 9.4)

4.3.1.3.2. Riverine plantation

The height of the tree ranged from 10.0 to 22.5 m with a mean of 15.7 m (cv 21.8). The diameter at collar showed a range of 19.9 to 9.4 cm with a mean of 13.4 m (cv 20.6). The diameter at breast height varied from 7.1 to 17.8 cm with a mean of 10.8 cm (cv 25.4). The stem showed a maximum of 83.5 kg and a minimum of 19.0 kg with a mean of 44.0 kg (cv 38.6). Bark weight ranged from 1.7 to 6.1 kg with a mean of 4.0 kg (cv 37.9). The branches weighed from 2.6 to 10.7 kg with a mean of 6.8 kg and a cv of 29.5. The needle weight ranged from 5.8 to 19.0 kg with a mean of 12.1 (cv 29.9). The roots weighed from 5.8 to 4.6 kg averaging 11.9 kg with a

Table 31. Components of biomass in coastal centre - Markkanam - VI Year

S. No.	Height m	Dia at collar cm	Dia at bh cm	Stem weight kg	Bark weight kg	Branch weight kg	Needle weight kg	Root weight kg	Total weight kg	% Stem	% Bark	% Branch	% Needle	% Root
1.	6.0	6.0	5.5	7.0	0.8	2.1	2.2	1.8	13.9	50.3	5.7	15.1	15.8	16.4
2.	7.0	7.6	4.6	8.5	0.9	2.2	2.7	1.9	16.2	52.4	5.5	13.6	16.6	16.7
3.	8.5	9.5	6.3	17.8	1.8	4.9	6.9	4.2	35.6	50.0	5.0	13.7	19.4	11.8
4.	10.0	8.9	7.3	29.5	2.1	5.8	9.2	6.5	53.1	55.5	3.9	10.9	17.3	12.2
5.	9.0	9.5	7.0	20.0	1.9	6.3	8.2	6.2	42.6	47.4	4.5	14.8	9.2	14.5
6.	12.0	11.9	8.0	34.0	3.2	4.7	9.5	7.5	56.9	59.7	5.6	8.3	16.7	13.2
7.	12.5	10.3	8.2	37.0	2.4	6.2	9.0	8.7	63.3	58.5	4.1	9.8	14.2	13.7
8.	14.0	15.5	12.7	56.0	4.9	12.7	18.0	14.0	105.6	53.0	4.6	12.0	17.0	13.2
9.	13.0	14.3	11.1	42.5	4.6	9.6	13.5	12.5	82.7	51.4	5.6	11.6	16.3	15.1
10.	9.5	11.1	7.0	20.0	2.1	4.5	6.8	5.9	39.3	50.9	5.3	11.5	17.3	15.0
11.	12.0	12.9	8.2	35.0	3.6	6.8	10.5	9.0	64.9	53.9	5.5	10.5	16.2	13.9
12.	13.0	12.4	8.2	32.0	3.4	5.2	9.5	9.4	59.5	53.8	5.7	8.7	15.9	15.3
13.	13.0	13.9	9.4	36.0	3.4	5.6	13.0	10.5	68.5	52.5	4.9	8.2	19.0	15.3
14.	10.0	11.4	7.6	26.5	2.7	3.4	7.5	7.9	48.0	55.2	5.6	7.0	15.6	16.4
15.	13.0	13.3	9.2	39.5	3.2	5.2	12.2	9.7	71.8	55.0	4.4	7.2	17.0	13.5
16.	12.0	12.6	9.9	38.5	3.2	7.3	13.0	10.5	72.5	53.1	4.4	9.7	17.9	14.4
17.	10.0	11.7	7.9	33.0	3.7	5.5	12.5	9.0	63.7	51.8	5.9	8.6	19.6	14.1
18.	11.0	10.8	7.1	20.0	1.9	3.5	7.1	5.8	37.3	53.6	5.1	9.1	19.0	15.5
19.	14.0	14.0	10.3	46.0	3.5	6.6	15.2	11.2	82.5	55.7	4.2	8.0	18.4	13.6
20.	13.0	13.0	9.2	34.0	2.9	4.7	13.0	9.2	63.5	53.3	4.5	7.4	20.4	14.4
Mean	11.1	11.5	8.2	30.6	2.8	5.6	9.9	8.0	57.0	53.3	5.0	10.3	16.9	14.1
cv%	20.0	20.0	22.9	38.9	37.4	41.4	38.5	38.4	38.0	5.1	12.0	23.9	13.8	9.4

cv of 34.9. The total weight of the tree ranged from a minimum of 35.1 kg to a maximum of 43.9 kg with a mean of 79.9 kg (cv 33.9). (Table 32; Fig. 20)

The various components of the tree showed the following average percentage and cv:

Stem	55.8 (cv 8.4)
Bark	5.0 (cv 14.9)
Branches	8.7 (cv 13.3)
Needle	15.4 (cv 13.9)
Root	15.2 (cv 22.7)

4.3.1.3.3. Inland plantation

The trees showed a height of 8.5 to 12.5 m with a mean of 10.6 m (cv 9.9). The diameter at collar ranged from 7.2 to 11.8 cm with a mean of 9.7 cm (cv 13.7). The diameter at breast height ranged from 5.3 to 8.9 cm with a mean of 7.2 cm (cv 13.6). The weight of stem varied from a minimum 12.0 to a maximum of 30.0 kg and averaged 21.7 kg (cv 20.6). The bark weight ranged from a minimum of 0.8 to a maximum of 2.4 kg with an average of 1.8 kg (cv 20.0). The weight of branches ranged from 2.0 to 4.0 kg with a mean of 2.9 kg (cv 17.8). The needle weight ranged from 3.5 to 6.0 kg with a mean of 4.7 (cv 15.5). The root component weighed from a minimum of

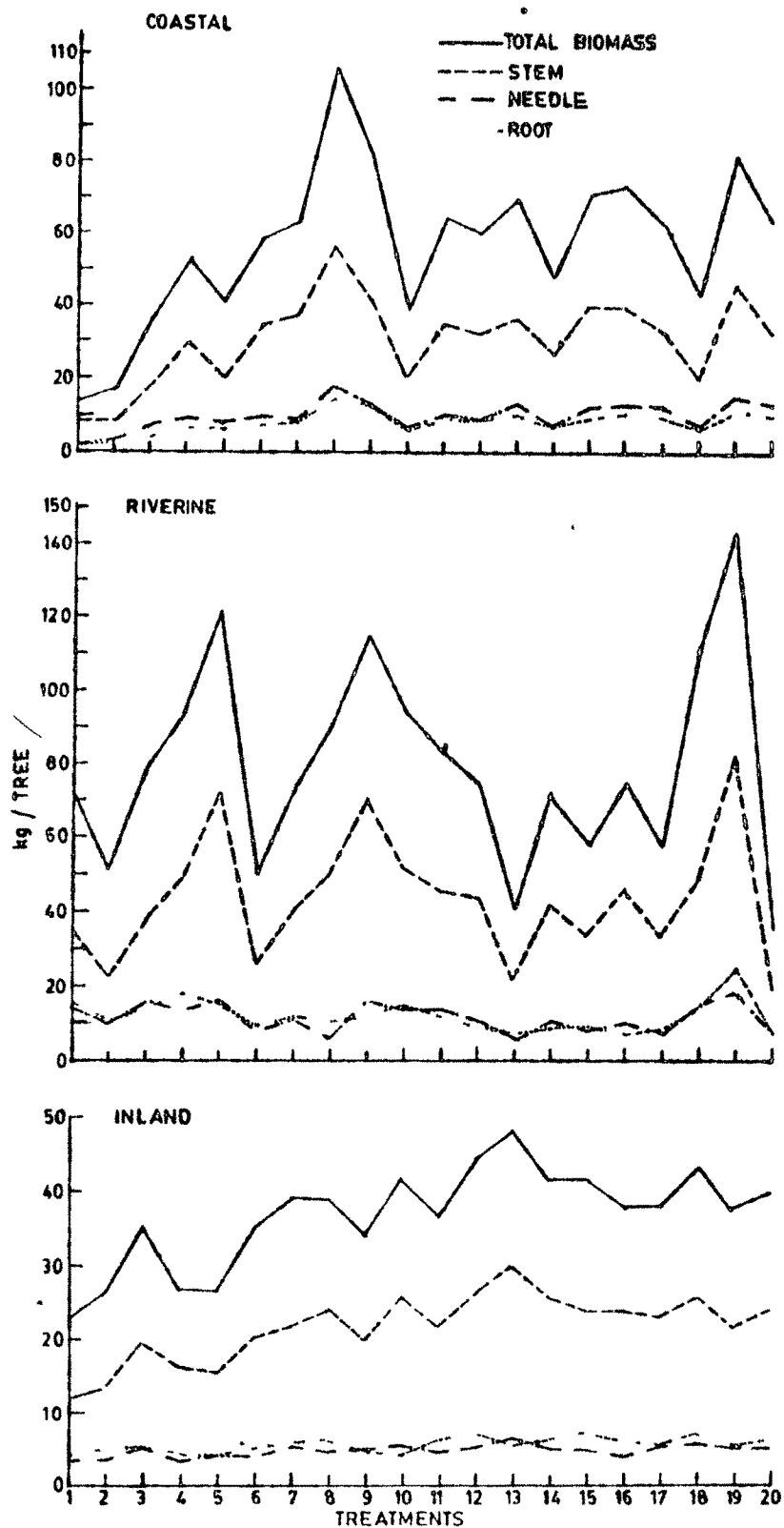


**FIG. 20 PARTITIONING OF BIOMASS COMPONENTS
IN SIX YEARS**

Table 32. Components of biomass in riverine centre - Natham - VI Year

S. No.	Height m	Dia at collar cm	Dia at bh cm	Stem weight kg	Bark weight kg	Branch weight kg	Needle weight kg	Root weight kg	Total weight kg	% Stem	% Bark	% Branch	% Needle	% Root
1.	15.0	9.4	8.0	36.2	3.1	6.0	14.0	15.6	74.7	48.4	4.1	8.0	18.7	20.9
2.	12.5	9.7	7.5	23.1	2.3	4.5	10.6	11.4	51.9	45.1	4.5	8.8	20.7	25.3
3.	14.0	12.5	9.5	38.3	3.3	7.8	15.5	13.5	78.5	48.9	9.9	9.9	19.8	17.2
4.	16.5	15.2	12.1	50.3	5.3	9.2	13.2	16.8	94.7	53.1	5.5	9.7	13.9	17.7
5.	21.0	16.5	14.6	73.4	6.7	10.0	16.5	15.2	121.8	60.3	5.5	8.2	13.5	12.5
6.	11.5	10.2	7.6	26.6	2.6	4.3	8.2	9.2	50.9	52.3	4.9	8.4	16.1	18.1
7.	18.8	12.6	9.7	40.0	4.5	6.2	10.0	11.5	72.2	55.4	6.2	8.6	13.9	15.9
8.	19.0	13.5	11.6	50.0	5.8	7.9	5.8	10.8	89.2	61.6	6.5	8.8	16.4	12.8
9.	18.3	17.2	14.6	70.6	6.9	9.2	16.5	12.0	115.2	61.3	5.9	7.9	14.3	10.4
10.	16.5	15.3	13.0	52.2	4.9	8.1	15.0	14.9	95.1	54.9	5.1	8.5	15.7	15.7
11.	17.5	14.9	12.1	46.4	4.1	7.9	13.5	12.0	83.9	55.3	4.9	9.4	16.0	14.3
12.	17.8	15.6	11.4	44.4	4.0	6.5	10.2	9.8	74.9	59.3	5.3	8.6	13.6	13.1
13.	10.0	10.5	8.3	21.6	1.9	4.6	6.5	7.0	41.6	51.9	4.6	11.0	15.6	13.5
14.	13.2	12.4	10.2	42.2	4.2	6.9	10.2	8.6	72.1	58.5	5.8	9.6	14.1	11.9
15.	12.0	11.8	9.2	34.3	2.9	5.8	7.7	8.9	59.7	57.4	4.9	9.7	12.9	14.9
16.	13.5	13.2	10.3	46.5	2.6	7.6	10.5	8.5	75.7	61.4	3.4	10.0	13.9	11.2
17.	12.0	12.4	8.9	34.0	2.9	5.2	8.8	8.0	58.9	57.7	4.9	8.8	14.9	13.6
18.	17.5	16.2	13.4	48.6	4.9	6.1	15.6	13.8	110.0	62.4	4.4	5.5	14.2	12.5
19.	22.5	19.9	17.8	83.5	6.1	10.7	19.0	24.6	143.9	58.0	4.2	7.4	13.2	17.1
20.	11.5	9.9	7.1	19.0	1.7	2.6	6.0	5.8	35.1	54.1	4.8	7.4	17.1	16.5
Mean	15.7	13.4	10.8	45.0	4.0	6.8	12.1	11.9	79.9	55.8	5.0	8.7	15.4	15.2
cv %	21.8	20.6	25.4	38.6	37.9	29.5	29.9	34.9	33.9	8.4	14.9	13.3	13.9	22.7

3.7 to 7.0 kg with an average of 5.5 kg (cv 17.2). The individual total weight of the tree ranged from 22.8 to 47.6 kg with a mean of 36.8 kg (cv 17.2) (Table 33; Fig.20).

The component parts of the tree showed the following percentage of distribution.

Stem	59.0 (cv 5.6)
Bark	4.8 (cv 14.7)
Branches	8.0 (cv 13.5)
Needle	13.2 (cv 9.9)
Root	14.7 (cv 15.3)

4.3.1.3.4. Correlation values

4.3.1.3.4.1. Coastal plantation

The traits like tree height, diameter at collar, diameter at breast height, stem weight, bark weight, branch weight, needle weight and root weight have shown positive correlation with total weight of the tree. The per cent of stem to total weight did not show significantly positive correlation. Branch per cent to total weight showed significantly negative correlation. There was no correlation with other characters (Table 34).

Table 33 Components of biomass in inland centre - Virudhachalam - VI Year

S. No.	Height m	Dia at collar cm	Dia at bh cm	Stem weight kg	Bark weight kg	Branch weight kg	Needle weight kg	Root weight kg	Total weight kg	% Stem	% Bark	% Branch	% Needle	% Root
1.	9.0	7.8	5.8	12.0	0.8	2.2	3.6	4.2	22.8	52.6	3.5	9.6	15.8	18.4
2.	11.0	8.7	6.6	13.5	1.6	3.0	3.7	5.1	26.9	50.2	5.9	11.2	13.8	18.9
3.	10.5	9.7	7.6	19.5	1.9	3.3	5.4	5.5	35.6	54.7	5.3	9.3	15.2	15.4
4.	8.5	7.2	5.6	16.5	1.2	2.1	3.5	3.7	27.0	61.1	4.4	7.7	12.9	13.7
5.	9.5	7.6	5.3	15.5	1.5	2.0	3.9	4.0	26.9	57.6	5.6	7.4	14.5	14.9
6.	10.0	8.7	6.5	20.5	1.8	2.8	4.0	4.8	34.9	61.6	5.2	8.0	11.5	13.8
7.	12.5	10.1	8.2	22.0	2.4	3.1	5.5	5.8	38.8	56.7	6.2	8.0	14.2	14.9
8.	10.0	11.5	7.6	24.0	2.1	3.0	4.5	5.8	38.6	62.2	5.4	7.7	11.6	15.0
9.	11.0	8.9	6.0	20.0	1.9	2.8	4.8	4.8	34.3	58.3	4.5	8.2	14.0	13.8
10.	12.1	9.5	7.0	26.0	2.2	3.9	5.5	4.2	41.8	62.2	5.3	9.3	13.2	10.0
11.	10.5	10.2	7.9	22.0	1.7	3.0	4.8	6.2	37.2	58.4	4.5	7.9	12.8	16.4
12.	11.5	10.1	8.2	26.5	2.2	3.0	5.0	6.8	43.5	59.8	5.0	6.9	11.1	15.6
13.	12.5	11.8	8.9	30.0	2.1	4.0	6.0	5.5	47.6	63.0	4.4	8.4	12.6	11.6
14.	11.0	10.8	8.3	26.0	1.6	3.2	4.8	6.3	41.9	62.0	3.8	7.6	11.5	15.0
15.	10.5	11.1	7.6	24.2	1.9	3.8	5.2	6.9	42.0	57.6	4.5	9.0	12.4	16.4
16.	9.5	9.5	6.4	24.0	2.1	2.5	3.7	5.9	38.2	62.8	5.5	6.5	15.4	9.6
17.	10.5	10.8	7.6	23.0	1.8	2.9	5.0	5.5	38.2	60.2	4.7	7.6	13.1	14.4
18.	11.5	11.5	7.6	26.0	1.7	3.1	5.6	7.0	43.4	59.9	3.9	7.1	12.9	16.1
19.	10.0	8.3	7.5	22.0	2.0	2.6	5.0	5.5	37.1	59.3	5.4	7.0	13.5	14.8
20.	10.6	10.6	8.1	24.0	1.6	2.9	4.8	6.2	39.8	60.7	4.1	7.4	12.2	15.6
Mean	10.6	9.7	7.2	21.7	1.8	2.9	4.7	5.5	36.8	59.0	4.8	8.0	13.2	14.7
cv%	9.9	13.7	13.6	20.6	20.0	17.8	15.5	17.2	17.2	5.6	14.7	13.5	9.9	15.3

Table 34. Correlation values for plant characters with biomass - Coastal centre - VI Year

S. No.	Character	Total Tree weight	Dia at collar	bh	Stem weight	Bark weight	Branch weight	Needle weight	Foot weight	Stem	Bark	Branches	Needles	Foot
1.	Total weight	0.8963	0.9095	0.9573	0.9923	0.9372	0.8500	0.9714	0.9800	0.3080	-0.3480	-0.4716	0.1604	-0.0578
2.	Tree height		0.9128	0.8723	0.9164	0.8352	0.6416	0.8673	0.9124	0.4807	-0.3510	-0.6694	0.2195	0.0449
3.	Dia at collar			0.9067	0.8937	0.9276	0.7020	0.9092	0.9389	0.2403	-0.1408	-0.5972	0.2843	0.0919
4.	Dia at bh				0.9496	0.9079	0.8586	0.9477	0.9659	0.2126	-0.3213	-0.4084	0.1735	0.0724
5.	Stem weight					0.9180	0.8194	0.9521	0.9655	0.4204	-0.3674	-0.5256	0.1702	-0.0814
6.	Bark weight						0.8029	0.9055	0.9513	0.2338	-0.0131	-0.4767	0.1900	0.0687
7.	Branch weight							0.8177	0.8152	-0.0027	-0.3139	0.0145	-0.0734	-0.1626
8.	Needle weight								0.9512	0.2027	0.3713	-0.4841	0.2704	0.0723
9.	Foot weight									0.2674	-0.2608	-0.5291	0.1420	0.1065
10.	Stem										-0.2021	-0.6479	0.1656	0.1765
11.	Bark											0.0949	0.0525	0.3812
12.	Branches												0.4390	-0.2074
13.	Needles													-0.1447
14.	Foot													..

4.3.1.3.4.2. Riverine plantation

The traits like tree height, diameter at collar, diameter at breast height, stem weight, bark weight, branch weight, needle weight and root weight showed highly significant correlation values with the total weight of the tree. Per cent stem showed a significant (5.0%) positive correlation with total weight. Per cent bark, per cent branches, per cent needle and per cent root showed nonsignificant negative values with total weight.

Per cent stem showed positive significant correlation tree height, diameter at collar, diameter at breast height, stem weight and bark weight besides total weight and negligible correlation with other traits.

Per cent bark showed highly significant values against bark weight but negative or negligible correlation with other traits. Per cent branches showed negative correlation with all the traits. Per cent needle showed significant negative value with diameter at breast height, diameter at breast height, stem weight, bark weight and per cent stem. Per cent root showed negative or negligible value for most traits except for per cent needle where it showed highly significant value (Table 35).

Table 35. Correlation values for plant characters with biomass - Riverine centre - VI Year

S. No.	Character	Total Tree weight	Tree height	Collar dia at br	Stem weight	Bark weight	Branch weight	Branch weight	Needle weight	Root weight	Stem	Bark	Branches	Needles	Root
1.	Total weight	0.8561	0.9087	0.9571	0.9665	0.9009	0.8982	0.8348	0.8191	0.4940	0.1165	-0.4274	-0.4110	-0.2814	
2.	Tree height		0.8156	0.8368	0.8766	0.8106	0.8120	0.6224	0.6646	0.5471	0.1828	-0.3582	-0.4254	-0.3011	
3.	Dia at collar			0.9761	0.9183	0.8391	0.8317	0.7032	0.6534	0.6265	0.1680	-0.3465	-0.5943	-0.4559	
4.	Dia at br				0.9592	0.8809	0.8706	0.7422	0.7257	0.5880	0.1658	-0.3648	-0.5397	-0.4038	
5.	Stem weight					0.9075	0.9255	0.7572	0.7310	0.5722	0.1878	-0.3153	-0.5123	-0.3850	
6.	Bark weight						0.8478	0.6344	0.6312	0.5521	0.5353	-0.3542	-0.4517	-0.3726	
7.	Branch weight							0.7356	0.7340	0.4037	0.1781	-0.0128	-0.3941	-0.3075	
8.	Needle weight								0.8224	0.0865	-0.1944	-0.3864	-0.0941	0.0141	
9.	Root weight									-0.0202	-0.1098	-0.3506	-0.0978	0.2548	
10.	Stem										0.3039	-0.2889	-0.7800	-0.8720	
11.	Bark										-0.0021	-0.2691	-0.2921		
12.	Branches											0.0738	-0.0331		
13.	Needles												0.6878		
14.	Root													..	

4.3.1.3.4.3. Inland plantation

Correlation values of traits like tree height, diameter at collar, diameter at breast height, stem weight, bark weight, branch weight, root weight and per cent stem were highly significant against total weight of the tree.

Per cent bark, per cent branches, per cent needle and per cent root showed negative correlation against total weight of the tree.

Per cent stem also showed highly significant correlation with stem weight. In other cases there was a weak or negligible correlation. Per cent bark showed negative or negligible correlation with all characters except bark weight. Per cent branches showed similar trend. Per cent needle weight showed negative correlation with all characters except bark and branch percentages where it was a feeble correlation. Per cent root showed mostly negative correlation against all characters barring per cent. branches that was also nonsignificant (Table 36).

4.3.2. Biomass increment

4.3.2.1. Total weight

The rate of increase in first year recorded in coastal and riverine centres over inland centre was 15.1 and

Table 36. Correlation values for plant characters with biomass - Inland Centre - VI Year

S. No.	Character	Total Tree weight	Dia at collar	Dia at bh	Stem weight	Bark weight	Branch weight	Needle weight	Root weight	% Stem	% Bark	% Branches	% Needles	% Root
1.	Total weight	0.6528*	0.7980*	0.8063*	0.9628*	0.6914*	0.7448*	0.8063*	0.6784*	0.6256*	-0.0748	-0.3742	-0.5580*	-0.3977
2.	Tree height		0.6674*	0.7305*	0.6503*	0.7075*	0.6182*	0.8549*	0.4994	0.0381	0.1937	0.1597	-0.2310	-0.1063
3.	Dia at collar			0.8558*	0.8204*	0.5644*	0.7674*	0.7574*	0.8118*	0.3163	-0.1298	-0.1316	-0.4532*	-0.0356
4.	Dia at bh				0.8045*	0.5938*	0.7374*	0.8023*	0.7826*	0.2613	-0.0513	-0.1526	-0.5235*	0.0246
5.	Stem weight					0.7171*	0.7391*	0.8038*	0.6704*	0.6833*	-0.0687	-0.4200	-0.5326*	-0.4644
6.	Bark weight						0.6242*	0.6647*	0.4932*	0.3515	0.5902*	-0.2240	-0.2521	-0.4416
7.	Branch weight							0.8082*	0.5208*	0.1972	0.0139	0.2826	-0.4041	-0.1780
8.	Needle weight								0.5815*	0.2729	-0.0382	-0.1109	-0.3262	-0.1629
9.	Root weight									0.1071	-0.0916	-0.2813	-0.3979	0.2131
10.	Stem %										-0.1261	-0.6765*	-0.4804*	-0.7691*
11.	Bark %											0.0648	0.1522	-0.2000
12.	Branches %												0.2092	0.3880
13.	Needles %													-0.0300
14.	Root %													..

85.9 per cent respectively. Increase was encountered with more emphasis in the third year where coastal centre showed 27.1 and riverine centre showed 141.4 per cent over the inland centre. An almost similar trend was maintained in the sixth year with 56.12 and 120.66 per cent increase respectively over inland by coastal and riverine centres. The riverine centre showed 61.4 per cent increased weight over coastal centre for similar growth period (one year) followed by 89.92 and 40.10 per cent over coastal in third and sixth years respectively (Table 37).

4.3.2.2. Height

In the first and third years, the coastal and riverine centres showed similar trends in increase in height growth over inland centre. But in the sixth year, the same vigour in increment could not be seen. Coastal centre showed a negligible 3.82 per cent increment in sixth year while 36.7 and 61.89 per cent increase was shown in the first and third year of growth respectively. The riverine centre had also slowed down against inland with 47.33 per cent increase in the sixth year as compared to 89.5 per cent of first year and 161.32 per cent increase in third year. The rapidity with which the riverine centre had gone through the mid phase (third year) and its decline in the sixth year indicated the possibility that the species had reached its lag phase or

Table 37. Increase in biomass over years in different locations

Year		Coast- al 1	River- ine 2	In- land 3	% Increase		
					1 ov- er 3	2 ov- er 3	2 ov- er 1
I	Total weight(g)	75.30	121.60	65.40	15.12	85.90	61.48
	Height(cm)	108.50	150.40	79.30	36.70	89.50	38.61
	Dia. at collar	0.85	1.23	0.69	27.53	78.26	39.77
	Stem weight(g)	51.53	83.95	44.50	15.79	88.65	62.91
	Needle weight(g)	12.81	20.21	10.84	18.17	86.43	57.76
	Root weight(g)	11.65	17.37	9.98	16.73	74.08	49.09
III	Total weight(kg)	5.06	9.61	3.98	27.13	141.45	89.92
	Height(cm)	371.70	600.00	229.60	61.89	161.32	61.42
	Dia. at collar(cm)	2.91	4.94	2.38	22.26	107.56	69.75
	Dia. at bh(cm)	1.99	3.85	1.64	21.34	134.75	93.46
	Stem weight(kg)	2.53	4.84	2.02	15.34	139.60	107.72
	Branch weight(kg)	0.83	1.34	0.66	25.75	103.03	61.44
	Needle weight(kg)	1.12	1.63	0.70	60.00	132.80	45.53
	Root weight(kg)	0.78	1.79	0.59	32.20	203.38	129.48
VI	Total weight(kg)	57.08	79.97	36.24	56.12	120.66	40.10
	Height(m)	11.12	15.78	10.71	3.82	47.33	41.90
	Dia. at collar(cm)	11.57	13.44	9.73	8.64	38.12	16.16
	Dia at bh(cm)*	8.22	10.84	7.23	13.69	49.93	31.87
	Stem weight(kg)	30.64	45.06	21.73	41.13	107.55	47.06
	Bark weight(kg)**	2.84	4.03	1.79	56.98	125.13	43.11
	Branch weight(kg)	5.64	6.85	2.96	90.54	131.41	21.45
	Needle weight(kg)	9.97	12.11	4.71	111.67	157.11	21.46
	Root weight(kg)	8.07	11.89	5.46	47.80	117.76	47.35

* Not recorded for first year

** Not recorded in first and third year since negligible quantity

had been limited in growth by competition for space and canopy closure at this environment.

The riverine centre that showed 38.61 per cent increase over the coastal centre in the first year had increased to 61.42 per cent in third year and 41.90 per cent in the sixth year (Table 37).

4.3.2.3. Diameter at collar

In the first year, the coastal and riverine centres had recorded 27.53 and 78.26 per cent increased growth over inland centre. During the same period, riverine centre exerted 39.77 per cent increased growth over coastal centre. At the third year stage, there was a variation in increment between the three. Coastal centre could record 22.26 per cent over inland but riverine centre showed 107.56 per cent more growth. For the same period, the riverine centre showed 69.75 per cent over coastal centre.

At the age of six, the coastal centre could show only 8.64 per cent increased growth against inland while riverine centre registered 38.12 per cent only. Between coastal and riverine centres, riverine centre showed an increase of 16.16 per cent over coastal centre.

4.3.2.4. Diameter at breast height (Dia at bh)

The riverine centre that showed 134.75 per cent increased growth in third year against the inland slowed down to 49.93 per cent in the sixth year. The coastal centre that registered an increase of 21.34 in the third year over inland declined to 13.69 per cent in the sixth year.

With regard to coastal, riverine centre could show an increase of 93.46 per cent during third year but it declined to 31.87 per cent in the sixth year.

4.3.2.5. Stem weight

The increase in stem weight that was 15.79 per cent over inland by coastal centre and 88.65 per cent over by riverine centre was maintained at 15.34 and 139.60 per cent respectively in the third year stage. The same trend was maintained at sixth year when coastal and riverine centres recorded 41.13 and 107.55 per cent more than inland. The decline in rate of growth was noticed for height. However it was not reflected in the diameter.

However, the yield increase of 107.72 per cent by the riverine centre over coastal centre during this period declined to 47.36 per cent in the sixth year.

4.3.2.6. Bark weight

This was recorded in the sixth year stage only. The increase recorded by riverine centre over inland was 125.13 per cent while coastal centre could show only 56.98 per cent. Between coastal and riverine centres, the latter scored an increase of 43.41 per cent.

4.3.2.7. Branch weight

Coastal centre could register 25.75 per cent increase over inland while riverine showed 103.03 per cent at the third year stage. The same trend was maintained at the VI year stage also where coastal centre showed a 90.54 per cent increase over inland.

Between coastal and riverine centres, the later showed 61.44 per cent increase in third year; however, it slowed down to 21.45 per cent increase in the sixth year.

4.3.2.8. Needle weight

The increase in needle weight by coastal and riverine centres over inland was consistent from the first year onwards, to the sixth year. Coastal centre showed high growth for needle maintaining 60.0 and 111.67 per cent increase during the third and sixth year growth period. The

riverine centre showed 132.8 and 157.11 per cent lead at both for the same periods.

When compared with the coastal centre the riverine centre could show a moderate increase of 57.76, 45.53 and 21.46 per cent increase during the first, third and sixth year period, showing a decline between the third and sixth year.

4.3.2.9. Root weight

Coastal centre showed consistent increase over inland at all the three growth periods recording an increase of 16.73, 32.2 and 47.8 per cent respectively while riverine centre showed better performance with 74.08, 203.48 and 117.76 per cent increase.

The riverine centre showed 49.09, 129.48 and 47.35 per cent increase over coastal centre at all the three growth period. The decline in root weight at the sixth year noticed in riverine centre is comparable to the decline of stem, branch and needle weights.

4.3.3. Biomass accretion in different centres over three ages

Biomass at first, third and sixth years was estimated earlier for the three different regions, and average

values for plant components and trees were estimated. Based on the survival per cent, the above ground and below ground biomass were extrapolated and presented in Table 38.

In the coastal area, the total biomass in the first year was only 181.5 kg, while in the third year it was 9512.8 kg. At the sixth year, the total was 99290.5 kg comprising 13960.0 kg of underground biomass (root) and 85330.5 kg of above ground components.

In the riverine area, the total extrapolated biomass based on the survival per cent was 297.0 kg in the first year, 20995.0 kg at the end of third year, and 174542.0 kg in the sixth year. The underground component was 26358.5 kg while the above ground biomass was 148183.5 kg.

In the inland area, the biomass at the end of first year was only 157.3 kg, followed by 8303.0 kg at the end of third year and 72285.0 kg at the end of sixth year. The below ground biomass was 10862.5 kg while the above ground biomass was 61422.5 kg.

4.4. LITTER-FALL IN PLANTATIONS

4.4.1. Litter-fall accumulation

4.4.1.1. Distribution of litter in various spaced plantations

The quantity of litter collected from four year old

Table 38. Total biomass production in I, III and VI year in different centre (kg/ha)

Centre / Age	Survival	Trees No./ha	Stem	Bark	Branch	Needle	Root	Total
Coastal								
I Year	95.6	2390	123.1			30.6	27.8	181.5
III Year	75.2	1880	4380.4		1560.4	2105.6	1466.4	9512.8
VI Year	69.8	1745	53397.0	4886.0	9772.0	17275.5	13960.0	99290.5
Riverine								
I Year	97.8	2445	205.2			49.4	42.4	297.0
III Year	88.4	2210	10608.0		2873.0	3536.0	3978.0	20995.0
VI Year	84.6	2215	97460.0	8860.0	15062.0	26801.5	26358.5	174542.0
Inland								
I Year	96.4	2410	107.2			26.1	24.0	157.3
III Year	87.4	2185	4370.0		1311.0	1529.5	1092.5	8303.0
VI Year	79.0	1975	42857.5	3555.0	5727.5	9282.5	10862.5	72285.0

Note: i. Bark and branch estimation was not done for first year
 ii. Bark estimation was not done for third year since it was negligible

plantations representing coastal area that have different espacements viz., 1.0 x 1.0 m, 1.5 x 1.5 m and 2.0 x 2.0 m was calculated on a quarterly basis and presented in Table 39 (Fig.21).

The amount of dry needle collected at the floor was low at 2.46 t for the plantation spaced 2.0 x 2.0 m while it was 2.61 and 3.03 t for the plantations having 1.5 x 1.5 m and 1.0 x 1.0 m spacing respectively. The amount of cones collected ranged from 0.42 t for 2.0 x 2.0 m, 0.44 t for 1.5 x 1.5 m and 0.52 t for the closer 1.0 x 1.0 m spaced plantation. The dry needle with inflorescence accumulated on the floor was 0.08, 0.07 and 0.05 t respectively for all the plantations. The accumulation by twigs was 0.75, 0.94 and 0.95 t for the 2.0 x 2.0 m, 1.5 x 1.5 m and 1.0 x 1.0 m spaced plantations. As a percentage, the amount of needle dropped was 66.3 per cent of the total for 2.0 x 2.0 m spaced plantation, 64.30 per cent for 1.5 x 1.5 m and 66.59 per cent for 1.0 x 1.0 m plantations.

The accretion was sorted on the basis of quarterly period. It was 38.2 per cent in I Quarter (April-June), 24.8 per cent in II Quarter (July-September), 20.8 per cent in III Quarter (October-December) and 16.1 per cent IV Quarter (January-March) for the plantations spaced 1.0 x 1.0 m. The

Table 39. Distribution of litter under different espacements

Spacing in m x m	Litter Compon- ents	Total quantiti- ty t/ha	% per quarter				% of Total
			I A-J	II J-S	III OC-D	IV* J-M	
1.0 x 1.0	Needle	3.03	38.2	24.8	20.8	16.1	66.59
1.0 x 1.0	Cones	0.52	33.5	30.4	13.7	22.4	11.43
1.0 x 1.0	Infl.	0.05	51.7	13.5	18.9	15.7	1.09
	Twigs	0.95	49.5	25.5	14.0	10.9	20.89
	Total	4.55	43.3	23.6	16.9	16.2	100.00
1.5 x 1.5	Needle	2.61	32.2	29.6	20.3	17.8	64.30
1.5 x 1.5	Cones	0.44	24.7	31.9	23.9	19.4	10.83
1.5 x 1.5	Infl.	0.07	59.7	14.0	14.1	12.2	1.72
1.5 x 1.5	Twigs	0.94	38.9	16.8	25.5	16.7	23.15
	Total	4.06	38.9	23.1	21.0	17.0	100.00
2.0 x 2.0	Needle	2.46	48.8	20.3	17.2	14.9	66.30
2.0 x 2.0	Cones	0.32	32.5	28.2	19.6	19.7	11.33
2.0 x 2.0	Infl.	0.08	58.6	18.1	12.5	10.8	2.15
2.0 x 2.0	Twigs	0.75	49.5	25.5	14.1	10.9	20.22
	Total	3.61	47.2	23.0	15.9	13.9	100.00

*A-J : April-June;

J-S : July-September

OC-D: October-December

J-M : January-March

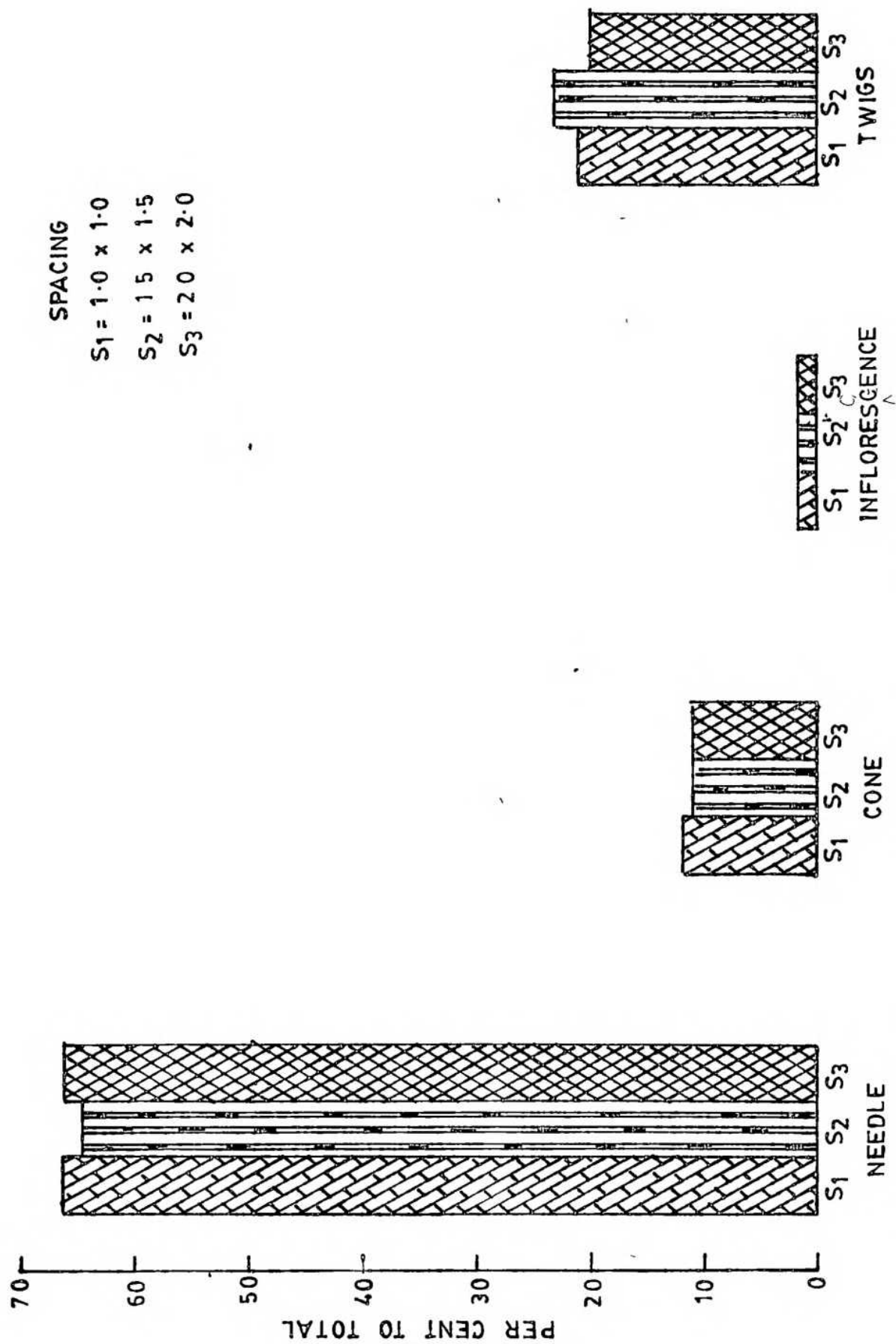


FIG. 21 LITTERFALL IN DIFFERENTLY SPACED COASTAL PLANTATIONS
 4 YEAR

percentage was almost similar for 1.5 x 1.5 m spaced plantation. The first quarter recorded 32.2 per cent, second quarter 29.6 per cent, third quarter 20.3 per cent and fourth quarter 18.1 per cent. However, in the widely spaced plantation of 2.0 x 2.0 m, the first quarter showed 48.8 per cent, second quarter 20.3 per cent, third quarter 17.2 per cent and fourth quarter 14.9 per cent.

The total annual cone drop amounted to 11.43, 10.83 and 11.33 per cent of the total litter-fall respectively for the three plantations. The closely spaced 1.0 x 1.0 m plantation registered 33.5, 30.4, 13.7 and 22.4 per cent cone drop for the four successive quarters. In the 1.5 x 1.5 m spaced plantation, the fall was 24.7, 31.9, 23.9 and 19.4 per cent for the quarters one to four. At the wider spacing of 2.0 x 2.0 m the fall was 32.5, 28.2, 19.6 and 19.7 per cent for the four quarters.

The annual drop of male inflorescence accounted for 1.09, 1.72 and 2.15 per cent of the litter respectively in the three different plantations. The male inflorescence showed maximum fall of 51.7 per cent during the first quarter followed by 13.5, 18.9 and 15.7 per cent in the second, third and fourth quarters respectively. In the 1.5 x 1.5 m spacing, the fall was 59.7, 14.0, 14.1 and 12.2 per cent for the four quarters

in the sequence. In the widely spaced plantation at 2.0 x 2.0 m, the fall was 58.6, 18.1, 12.5 and 10.8 per cent respectively for the four quarters.

The twigs accounted for 20.22, 23.15 and 20.89 per cent of the total annual litter-fall in the three espacements. The twig fall was 49.5, 25.5, 14.0 and 10.9 per cent in the first, second, third and fourth quarter respectively for the plantation spaced 1.0 x 1.0 m. The plantation with a spacing of 1.5 x 1.5 m had a twig fall of 38.9, 16.8, 25.5 and 18.7 per cent for the respective four quarters. The wider spacement of 2.0 x 2.0 m registered similar trend with 49.5, 25.5, 14.1 and 10.9 per cent for the four quarters. It was generally more in the first quarter for all the three plantations.

4.4.1.2. Distribution of litter in similarly spaced plantation of coastal and riverine areas at two different ages

4.4.1.2.1. Litter-fall in four year old plantations

The litter-fall in the coastal and riverine areas were compared on the basis of the age of the plantation.

A four year old plantation of coast, recorded a total litter of 3.72 t while a riverine plantation recorded 5.7 t.

Both were planted with a spacing of 2.0 x 2.0 m. The per cent of litter components varied for cone, inflorescence and twigs but was identical for needle. Coastal plantation recorded higher per cent of cone (11.4 per cent in coastal and 8.3 per cent in riverine), more male inflorescence (2.2 and 1.7 per cent in coastal and riverine plantations respectively). The twig fall was high in the riverine (24.7%) as compared to the coastal area (20.2%) Table 40; Fig.22).

However, the distribution of litter-fall over the period followed a parallel trend between the two plantations. The first quarter recorded maximum litter-fall followed by second quarter. The third quarter showed the lowest percentage and the fourth quarter slightly higher fall.

The increase in dry needles in the litter of the riverine plantation is 54.49 per cent than the coastal plantation. Similarly cone registered 13.2 per cent and twigs registered 88.69 per cent more when compared to the coastal plantation. Regarding the seasonality, the first quarter of the year recorded maximum litter-fall followed by the second as reported earlier.

4.4.1.2.2. Litter-fall in six year old plantations

The litter-fall in six year old riverine and coastal

Table 40. Litterfall in Coastal and Riverine plantations

2 x 2 m

	Litter fall compon- ent	Quan- tity kg	% per quarter				% to Total
			I Qr %	II Qr %	III Qr %	IV Qr %	
<u>Age: 4 Years</u>							
Coastal	Needle	2468	48.8	20.3	17.2	14.9	66.2
	Cone	424	41.6	28.2	10.6	19.6	11.4
	Infl.	81	58.5	18.1	12.5	10.8	2.2
	Twigs	752	49.5	25.5	14.1	10.9	20.2
	Total	3725	49.6	23.0	13.6	14.0	100.0
Riverine	Needle	3760	35.4	27.6	13.5	22.5	65.3
	Cone	480	39.7	22.1	17.2	21.0	8.3
	Infl.	96	52.8	18.2	17.6	12.4	1.7
	Twigs	1419	59.6	19.4	9.3	11.7	24.7
	Total	5755	46.8	21.8	14.4	16.9	100.0
<u>Age: 6 Years</u>							
Costal	Needle	3458	39.5	29.8	11.0	20.7	57.4
	Cone	618	44.3	21.4	13.6	20.7	10.3
	Infl.	105	64.4	17.8	6.2	11.6	1.7
	Twigs	1842	54.8	22.7	8.3	14.2	30.6
	Total	6023	50.7	22.9	9.7	16.8	100.0
Rinverine	Needle	6120	37.6	23.8	11.4	21.2	62.4
	Cone	690	49.7	23.5	9.0	19.2	7.0
	Infl.	126	58.2	21.2	7.0	13.6	1.3
	Twigs	2875	48.6	29.4	8.5	14.5	29.3
	Total	9811	48.5	24.5	8.9	18.9	100.0

I Qr : April-June
II Qr : July-Sept.

III Qr : Oct-Dec.
IV Qr : Jan-March

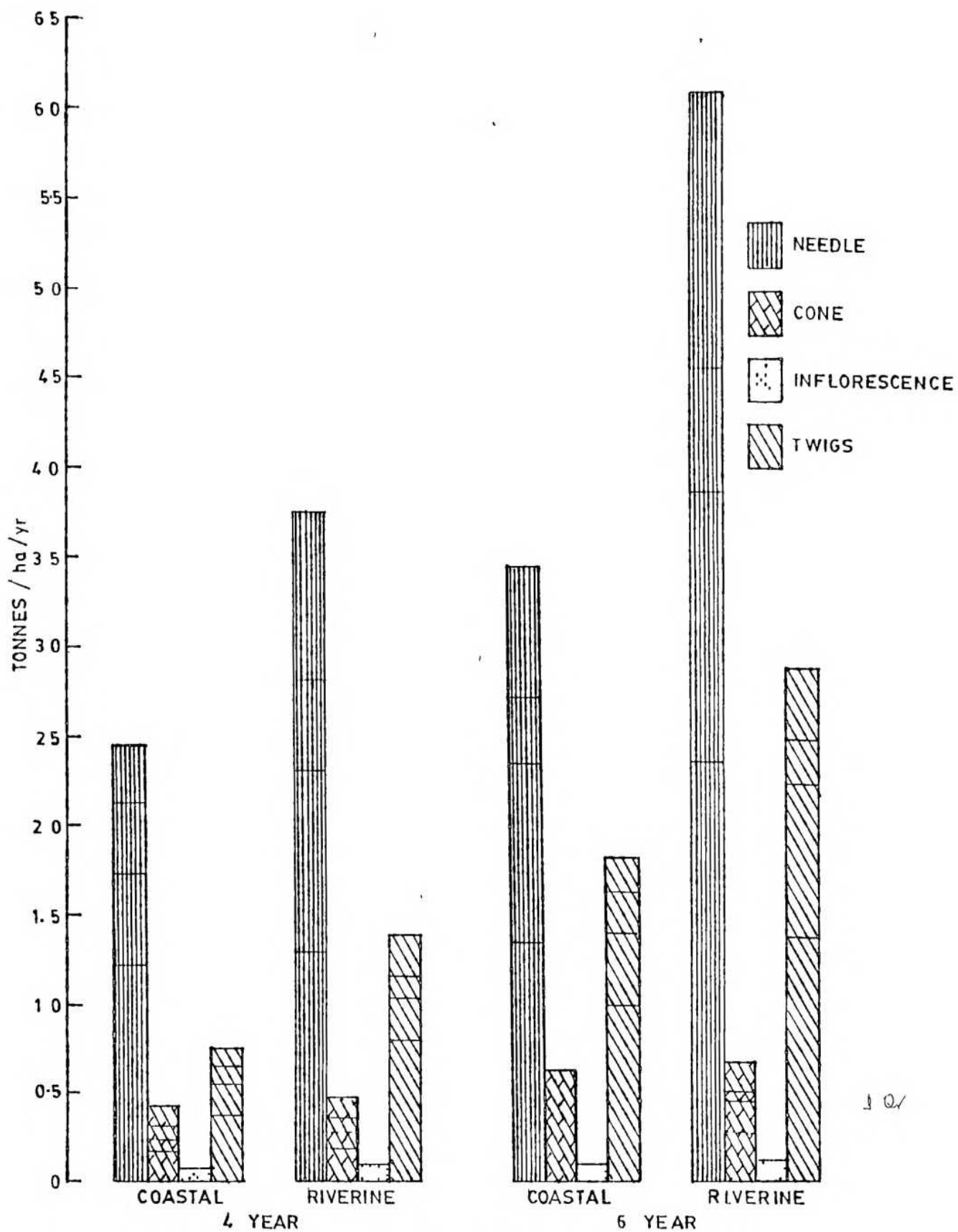


FIG 22 ANNUAL LITTERFALL IN SIMILARLY SPACED COASTAL, RIVERINE PLANTATIONS 4 & 6 YEARS OLD

plantations was monitored. The riverine plantation recorded a total of 9.81 t while the coastal plantation showed 6.02 t. The increase in needle fall was very high (78.5 per cent) in the riverine plantation while the increase in cone was low (11.65 per cent). The inflorescence in riverine area also showed a low value of 20.0 per cent (Table 40; Fig.22).

4.5. NUTRIENT STATUS IN PLANTS AND SOILS OF CASUARINA PLANTATION

4.5.1. Plantations of differing environments

Plantations of four and six year but representing coastal and riverine areas were analysed for nutrients in the litter and also in plant components like stem, branch, bark and root.

4.5.1.1. Mineral content in 4 year plantations

The accumulation of ash in the needle was 9.9 per cent in riverine samples while it was 8.4 per cent in coastal samples. The cone, inflorescence and twigs also showed higher rates of ash content in riverine samples. Calcium accretion was low in the riverine samples, but cone and inflorescence showed increased levels ranging from 0.15 to 0.22 per cent. Magnesium levels were similar in both the cases. Nitrogen was slightly higher in needles of four year riverine sample, followed by inflorescence and bark. The twigs showed lesser (0.81%) nitrogen content against 0.93 per cent of

coastal samples. Phosphorus content was almost identical in both cases. There was no major deviation for potassium between the two centres.

Because of the differences in mineral content and the biomass produced at the two different environments, the harvestable minerals were distinctly higher in the riverine plantation. It carried an increase of 84.3 per cent ash, 18.60 per cent calcium, 53.77 per cent magnesium, 57.09 per cent nitrogen, 46.12 per cent phosphorus and 0.60 per cent potassium over coastal samples (Table 41).

4.5.1.2. Mineral content in 6 year plantations

Ash content in the needles of riverine areas showed an increase of nearly 48.2 per cent over coastal samples. This was reflected in cone, inflorescence, stem and root. Calcium was high in the needles of coastal areas than that of riverine samples. Compared to the calcium content in the needles, the calcium content in the barks of coastal centre was higher. The difference was higher in riverine samples. Magnesium absorption in the needle was vastly different in the two materials, coastal samples showing lesser (0.27%) magnesium than that of riverine (0.42%) samples. The stem has a tendency to retain comparatively higher magnesium in the riverine areas.

Table 41. Mineral content in plant parts from IV Year plantations (% on dry basis)

Centre	Litter	Ash	Ca	Mg	N	P	K
Coastal	Needle	8.47	2.49	0.30	1.68	0.190	0.36
	Cone	7.98	0.98	0.27	1.25	0.010	0.36
	Infl.	5.12	0.75	0.24	0.50	0.012	0.25
	Branch	5.92	1.10	0.21	0.93	0.012	0.27
	Stem	8.57	0.90	0.27	0.24	0.019	0.14
	Bark	9.20	2.30	0.21	0.49	0.012	0.33
	Root	7.70	1.40	0.29	0.51	0.030	0.29
Riverine	Needle	9.90	1.80	0.29	1.78	0.180	0.37
	Cone	8.30	1.20	0.21	1.10	0.012	0.35
	Infl.	6.90	0.90	0.23	0.70	0.090	0.31
	Branch	8.70	1.00	0.27	0.80	0.010	0.29
	Stem	9.90	0.90	0.36	0.41	0.010	0.14
	Bark	10.90	2.30	0.22	0.63	0.010	0.20
	Root	8.30	1.50	0.27	0.62	0.020	0.25

Nitrogen in the needle of coastal sample was lower by 0.24 per cent against 1.95 per cent of the riverine samples. However, bark and twigs of coastal samples showed more nitrogen than their counter parts of riverine samples. Stem had retained the lowest nitrogen (0.31%) characteristic of woody species. Phosphorus was less, except the needle tended to store a higher per cent. Potassium was consistently high in most plant parts, in both the situations except bole that showed a low of 0.15 per cent against 0.42 of the needle in coastal centre. But the riverine samples showed a high level of 0.52 per cent in the needle and 0.19 per cent in the bole (Table 42).

4.5.1.2.1. Comparison between four and six year old coastal plantations

The mineral content in plant components of the four and six year old plantations had shown differences. The ash content of bark in six year old trees was 11.2 per cent which was higher than that of the four year old (9.2%). The twig and stem also showed comparatively higher levels of ash content. Calcium level was almost identical in both the cases, except for bark that was high by 0.4 per cent in the older plantation.

The level of magnesium was distinctly high in the older plantation that ranged from 0.25 to 0.42 per cent for

Table 42. Mineral content in plant parts from VI Year plantations (% on dry basis)

Centre	Litter	Ash	Ca	Mg	N	P	K
Coastal	Needle	8.70	2.40	0.27	1.71	0.170	0.42
	Cone	8.00	0.90	0.42	0.95	0.010	0.47
	Infl.	6.10	0.60	0.39	0.56	0.012	0.37
	Branch	7.40	1.30	0.27	0.72	0.011	0.45
	Stem	9.70	0.80	0.32	0.31	0.014	0.15
	Bark	11.20	2.70	0.25	0.53	0.090	0.27
	Root	7.50	1.50	0.42	0.49	0.016	0.44
Riverine	Needle	12.90	1.98	0.42	1.95	0.200	0.52
	Cone	10.90	1.10	0.27	0.89	0.014	0.49
	Infl.	9.40	0.50	0.32	0.65	0.010	0.37
	Branch	7.80	1.20	0.39	0.55	0.012	0.39
	Stem	10.70	0.90	0.42	0.45	0.010	0.19
	Bark	10.70	2.90	0.29	0.58	0.009	0.31
	Root	9.50	1.81	0.39	0.61	0.019	0.45
Inland	Needle	8.90	1.90	0.25	1.70	0.200	0.45
	Cone	6.50	0.70	0.21	0.78	0.010	0.27
	Infl.	5.70	0.80	0.29	0.65	0.012	0.22
	Branch	6.20	0.90	0.29	0.81	0.013	0.25
	Stem	7.80	0.80	0.19	0.32	0.010	0.12
	Bark	8.50	2.20	0.21	0.45	0.011	0.17
	Root	7.70	1.30	0.27	0.49	0.015	0.32

the different components while it was 0.21 to 0.30 per cent for the younger plantation. The nitrogen content in needles of both the plantations was almost identical but the nitrogen content in the cones of younger plantation was higher by 0.3 per cent compared to the older plantation. Bark of older plantation stored more nitrogen (0.53%) than the bark of younger plantation (0.49%). Phosphorus levels were similar in both the situations. Potassium levels were higher in older plantation ranging from 0.15 to 0.47 per cent while younger plantation showed 0.14 to 0.36 per cent. Cone stored more potassium than most other components, followed by root.

4.5.3.2.2. Comparison between four and six year old riverine plantations

The ash content in four year old stem was 9.9 per cent while in older six year trees it was higher (10.7%). Needle, cone, male inflorescence and root of six year trees showed increased levels of ash. With regard to calcium, branch, bark, root, needle and cone have accumulated more in plant parts at six years than at four years. Magnesium accumulation was also more in older trees than younger trees. There was a decrease of nitrogen in cone, inflorescence, branches, bark and root in older trees, but the needles have added 0.17 per cent more with age. Phosphorus levels have gone up in needle, cone, branches but not in others. Potassium showed an increase in older plants than in younger ones, almost in all parts (Table 42).

45.1.2.3. Nutrient content in plant litter of coastal and riverine plantations

The mineral yield in plant litter of four and six year old coastal and riverine plantations varied widely due to their biomass and also nutrient status of their sites. The riverine plantations yielded more than two fold in ash content, magnesium, phosphorus and potassium at six years. At four years, ash yield was almost double, but contribution of calcium, nitrogen, magnesium, phosphorus and potassium were very high. This increased contribution is largely due to the total litter-fall that ranged at 3725 kg/ha for coastal and 5755 kg/ha for riverine plantations at four years. At the age of six years, the total litter yield was 6023 kg/ha in coastal and 9811 kg/ha in riverine plantations. In all the situations, needle contributed more than sixty per cent to the total (Table 43).

4.5.2. Plantations differing in espacement

4.5.2.1. Nutrient content in litter of varying espacement in four year old coastal plantation

The mineral contribution by the litter of differently spaced coastal plantations varied according to the density of population. In the 1.0 x 1.0 m spacing, 3030 kg of dry needle provided 256.6 kg of ash, 75.4 kg of calcium, 9.0 kg of Mg, 50.9 kg of N, 5.75 kg of P and 10.9 kg of K

Table 43. Total mineral content in plant litter from coastal and riverine plantations of 4 and 6 years (per annum (kg/ha))

Centre	Litter component	Quantity	Ash	Ca	Mg	N	P	K
<u>4 Years</u>								
Coastal	Needle	2468	209.0	61.2	7.4	41.4	4.7	8.9
	Cone	424	33.8	4.1	1.1	5.3	tr	1.5
	Infl.	81	4.1	0.6	0.2	0.4	tr	0.2
	Twigs	752	44.5	8.2	1.5	6.9	0.1	2.0
	Total	3725	291.4	74.1	10.2	54.0	4.8	12.6
Riverine	Needle	3760	372.2	67.7	10.9	66.9	6.7	13.9
	Cone	480	39.8	5.7	1.0	5.3	tr	1.7
	Infl.	96	6.6	0.8	0.2	0.7	tr	0.3
	Twigs	1419	123.4	14.2	3.8	11.3	0.1	4.1
	Total	5755	542.0	88.4	15.9	84.2	6.8	20.0
<u>6 Years</u>								
Coastal	Needle	3458	300.8	83.0	9.4	59.1	5.9	14.5
	Cone	618	49.4	5.6	2.6	5.9	0.1	2.9
	Infl.	105	6.4	0.6	0.4	0.7	tr	0.4
	Twigs	1842	136.0	23.9	4.9	13.2	0.2	8.3
	Total	6023	492.6	113.1	17.1	78.9	6.2	26.1
Riverine	Needle	6120	789.5	121.1	25.7	119.5	12.2	31.8
	Cone	690	75.2	7.6	1.8	6.1	0.1	3.4
	Infl.	126	11.8	0.6	0.4	0.8	tr	0.4
	Twigs	2875	224.2	34.5	11.2	18.7	0.3	11.2
	Total	9811	1098.7	163.9	39.1	144.9	12.6	46.8

per year. The cones, inflorescence and twigs contributed the remaining 100.5 kg of ash, 15.9 kg of calcium, 3.4 kg of Mg, 15.6 kg of N, 0.17 kg of P and 4.57 kg of K to the soil environment. In the second series of plantations having wider spacing of 1.5 x 1.5 m, the ash content per unit area was lower than 1.0 x 1.0 m espacement, recording a total of 315.5 kg followed by 80.0 kg of Ca, 11.6 kg of Mg, 58.5 kg of N, 5.11 kg of P and 13.7 kg of K. The needle was the largest contributor of minerals among the various components as in the case of 1.0 x 1.0 m spaced plantation (Table 44; Fig. 23).

In the widely spaced (2.0 x 2.0 m) plantation, the quantum of litter-fall was lower than the previous two plantations, recording a total of 3725 kg. The total ash obtained from this litter was 291.46 kg, calcium 75.20 kg, magnesium 10.24 kg, nitrogen 54.20, phosphorus 4.90 kg and potassium 12.62 kg. Among all the components of litter, needle contributed 71.7 per cent ash, 81.6 per cent calcium, 72.26 per cent of magnesium, 76.56 per cent of nitrogen, 95.5 per cent of phosphorus and 70.52 of potassium.

4.5.3. Cumulative yield of nutrients in six year old plantations - per annum basis

The nutrient potential of live plantations of six year old coastal riverine, and inland plantations was worked

Table 44. Accretion of nutrients through litter components in differently spaced plantations of coastal centre (kg/ha/yr) at age 4 years

Spacing	Litter	Quantity	Ash	Ca	Mg	N	P	K
1.0x1.0	Needle	3030	256.60	75.40	9.00	50.90	5.75	10.90
	Cones	520	41.50	5.90	1.40	6.50	0.05	1.87
	Infl.	52	2.70	0.40	0.10	0.30	0.01	0.13
	Twigs	952	56.30	10.40	1.90	8.80	0.11	2.57
	Total	4554	357.10	91.30	12.40	66.50	5.92	15.47
1.5x1.5	Needle	2610	221.00	64.90	7.80	43.90	4.95	9.40
	Cones	440	35.10	4.30	1.20	5.50	0.04	1.60
	Infl.	74	3.80	0.50	0.10	0.40	0.01	0.20
	Twigs	940	55.60	10.30	1.90	8.70	0.11	2.50
	Total	4064	315.50	80.00	11.60	58.50	5.11	13.70
2.0x2.0	Needle	2468	209.00	61.41	7.40	41.50	4.68	8.90
	Cones	424	33.82	4.15	1.14	5.30	0.04	1.52
	Infl.	81	4.13	1.40	0.18	0.44	0.10	0.20
	Twigs	752	44.51	8.25	1.52	6.96	0.08	2.00
	Total	3725	291.46	75.20	10.24	54.20	4.90	12.62

$S_1 = 1.0 \times 10 \text{ m}$
 $S_2 = 15 \times 15 \text{ m}$
 $S_3 = 20 \times 20 \text{ m}$

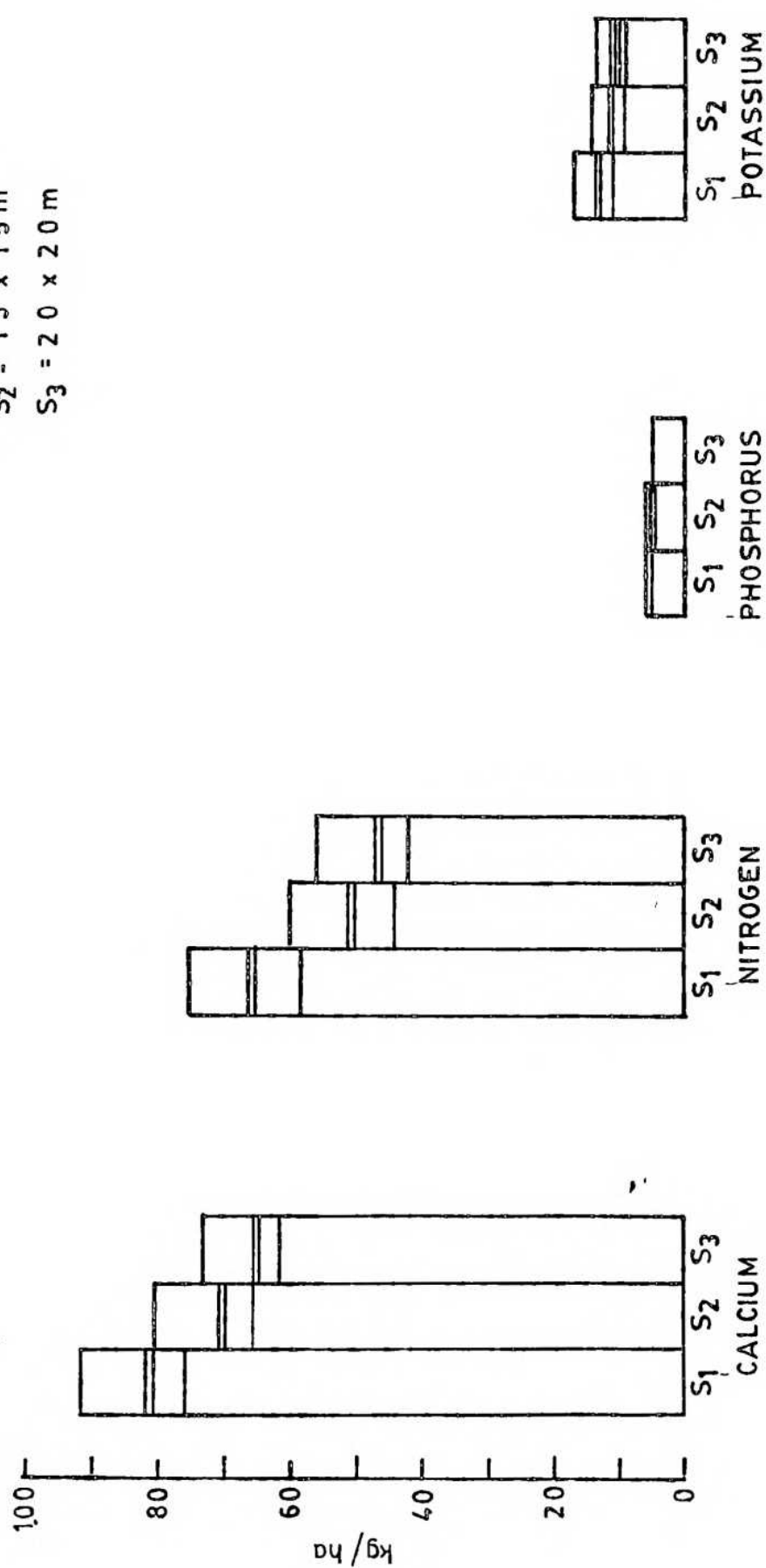


FIG. 23 NUTRIENT CONTENT IN LITTER OF DIFFERENT SPACED PLANTATION

out based on the mineral content of the plant components. The biomass was worked out on a per year basis and the nutrient yield computed for presentation.

4.5.3.1. Coastal plantation

The cumulative yield of ash was 1499.5 kg of which stem contributed 57.5 per cent, followed by needle (16.69 per cent). Calcium accretion was 218.6 kg, contributed equally by stem and needle amounting to 32.52 and 31.61 per cent respectively. Magnesium (52.2 kg) was largely contributed by stem (54.59, per cent). Needle contributed 49.2 kg nitrogen (47.2 per cent) and 27.6 kg by stem (26.48 per cent). Needle held more phosphorus (73.8 per cent) and stem contributed 18.5 per cent of the total 6.5 kg. Potassium (45.10, per cent) was contributed largely by stem (29.49 per cent) and needle (26.82 per cent) (Table 45).

4.5.3.2. Riverine plantation

The total biomass calculated was 29090 kg. They contributed 2865.2 kg ash, about 91.07 per cent more than that of coastal plantation. The total amount of calcium contributed by all the components was 386.0 kg, of which 37.7 per cent was from the stem while the needles had 22.84 per cent. The total magnesium content of all the components was 118.1 kg of which the stem contributed 57.7 per cent. Nitrogen accumulation was

Table 45. Total mineral content in plant components from coastal, riverine and inland plantations - per annum (kg/ha)

Centre	Component	Quantity	Ash	Ca	Mg	N	P	K
Coastal	Stem	8899	863.2	71.1	28.5	27.6	1.2	13.3
	Bark	814	91.1	21.9	2.0	4.3	tr	2.2
	Branch	1628	120.4	21.6	4.3	11.7	0.1	7.3
	Needle	2879	250.4	69.1	7.7	49.2	4.8	12.1
	Root	2326	174.4	34.9	9.7	11.4	0.4	10.2
	Total	16546	1499.5	218.6	52.2	104.2	6.5	45.1
Riverine	Stem	16243	1518.0	146.1	68.2	73.0	1.6	30.8
	Bark	1476	157.9	42.8	4.3	8.6	0.1	4.6
	Branch	2510	195.8	30.1	9.8	13.8	0.3	9.8
	Needle	4467	576.2	88.4	18.7	87.1	8.8	23.2
	Root	4393	417.3	79.5	17.1	26.8	0.8	19.7
	Total	29090	2865.2	386.9	118.1	209.3	11.6	88.1
Inland	Stem	7143	557.1	57.1	13.5	22.8	0.7	8.5
	Bark	592	50.3	13.0	1.2	2.6	tr	1.0
	Branch	954	59.1	8.5	2.7	7.7	0.1	2.3
	Needle	1547	137.6	29.3	3.8	26.3	3.1	6.9
	Root	1810	139.4	23.5	4.8	8.8	0.2	5.7
	Total	12046	943.5	131.4	26.0	68.2	4.1	24.4

209.3 kg where the needles held 41.61 per cent, followed by stem at 34.87 per cent. Phosphorus content in the biomass was 11.6 kg of which 8.8 kg and 1.6 kg were contributed by needle and stem respectively. Potassium was essentially contributed by stem and needle followed by branches. The total quantity of 88.10 kg was shared by stem, needle and branches at 34.9, 36.33 and 22.36 per cent respectively (Table 45).

4.5.3.3. Inland plantation

The availability of ash was considerably low at 943.5 kg, the lowest among the three plantations. Both needle and root contributed equally, but the stem, because of its high biomass contributed to 59.0 per cent. Calcium figured at 131.4 kg of which stem, needle and root contributed 43.45, 22.29 and 17.88 per cent respectively. Magnesium was lowest both on account of low biomass and less content in plant parts. Totally it was 26.0 kg of which 51.9 per cent came from stem and 33.07 per cent from needle and roots.

Though nitrogen content was high in the needles, stem also equally contributed 33.43 per cent of the total 68.2 kg. The contribution of needles was 38.56 per cent. Phosphorus accumulation in the biomass was 4.1 kg of which 75.6 per cent was contributed by needle. Potassium

accumulated to 24.4 kg largely owing to stem and needle, and followed by root (Table 45).

4.5.4. Nutrient status in soils of Casuarina plantations

4.5.4.1. Coastal plantation

The pH of the soil remained uniform in the first year of cultivation at all depths. It was 7.7 in the 0-20 cm top layer; the deep layer at 80-100 cm recorded pH of 7.9.

The second year of culture, the pH in the soil profile ranged from 7.6 in the top 0-20 cm layer to 7.8 in the 80-100 cm layer.

In the third year, there was a slight drop in the pH to 7.5 at the 0-20 cm layer, followed by 20-40 cm where it was 7.1; the 40-60 cm layer showed 7.2 but the pH rose to 7.5 and 7.7 at the 60-100 cm layer.

The pH decreased further to 6.9 in the top 0-20 cm layer in the fourth year followed by 7.5 in the 20-40 cm layer. Deep below, it ranged from 7.1 to 7.4.

At the sixth year, the soil reaction was slightly acidic at 6.7 in the top 0-20 cm layer and it ranged from 7.2 to 7.5 in the sub soil (Table 46).

Table 46. Nutrient status of soil profile in Coastal area -
Marakkanam centre under Casuarina

Age	Soil profile cm	pH	EC mmhos/ cm ²	OC %	Available nutrients (kg/ha)			
					Ca	N	P	K
Control	0-20	7.9	0.46	0.83	18.23	85.0	7.3	240
	20-40	7.8	0.48	0.31	10.94	42.0	5.1	236
	40-60	7.8	0.47	0.22	7.85	27.0	4.7	227
	60-80	7.7	0.46	0.19	10.12	19.6	5.0	246
	80-100	7.8	0.49	0.21	9.99	20.4	4.5	250
I Year	0-20	7.7	0.46	0.79	17.92	85.8	7.5	250
	20-40	7.9	0.47	0.32	9.51	49.0	5.9	218
	40-60	7.8	0.44	0.29	10.52	32.0	4.2	231
	60-80	7.6	0.49	0.17	9.96	11.6	4.9	239
	80-100	7.9	0.41	0.20	11.65	10.7	5.2	252
II Year	0-20	7.6	0.41	0.88	16.9	92.0	7.9	240
	20-40	7.5	0.43	0.35	8.5	52.6	6.1	235
	40-60	7.9	0.45	0.31	11.6	27.0	4.9	230
	60-80	7.4	0.41	0.19	8.7	9.8	5.5	241
	80-100	7.8	0.49	0.21	10.8	10.5	4.9	259
III Year	0-20	7.5	0.46	1.02	18.1	99.5	8.1	245
	20-40	7.1	0.45	0.41	10.1	59.1	5.9	270
	40-60	7.2	0.43	0.34	6.5	30.4	7.0	230
	60-80	7.5	0.37	0.25	5.9	10.5	4.9	274
	80-100	7.7	0.40	0.12	8.8	11.6	4.8	250
IV Year	0-20	6.9	0.39	1.19	19.6	109.8	9.7	270
	20-40	7.5	0.41	0.42	10.1	62.5	6.0	267
	40-60	7.1	0.45	0.34	7.5	37.6	5.1	293
	60-80	7.2	0.40	0.29	7.9	19.0	4.9	265
	80-100	7.4	0.42	0.19	8.9	21.6	5.2	253
VI Year	0-20	6.7	0.41	1.32	23.0	125.5	9.8	290
	20-40	7.2	0.39	0.70	10.6	80.6	7.1	277
	40-60	7.3	0.42	0.34	10.1	32.1	5.6	235
	60-80	7.5	0.49	0.22	7.8	27.8	5.2	250
	80-100	7.4	0.39	0.39	6.5	19.5	4.9	265

Electrical conductivity (EC mmhos/cm²)

The EC of the soil was slightly higher at all depths in the profile. In the uncropped control plot the EC remained between 0.46 to 0.49 in the soil profile. In the one year old plantation, it did not change and followed that of the control. The two year old plantation showed a slight reduction in the EC value recording 0.41 in the top layer (0-20 cm) and 0.49 at 80-100 cm layer. The three year old plantation registered values 0.46 to 0.37 at the different horizons. The four year old plantation recorded further reduction from 0.39 to 0.42. The reduction was appreciable in the 0-20 cm layer.

In the sixth year of cultivation, the reduction was not progressive. The EC remained at 0.41 at the top layer and deeper layers showed 0.39 (Table 46).

Calcium content (kg/ha)

The content of calcium in the soil was high in the surface layer followed by deeper layers. In the uncropped control it was 18.23 kg at the top 0-20 cm, 10.94 kg in the 20-40 cm layer, followed by 7.85 kg in the 40-60 cm layer. It increased slightly to 10.12 kg at 60-80 cm and further reduced to 9.99 kg in the 80-100 cm layer.

In the first year of cultivation, the calcium status did not change appreciably. The surface layer (0-20 cm)

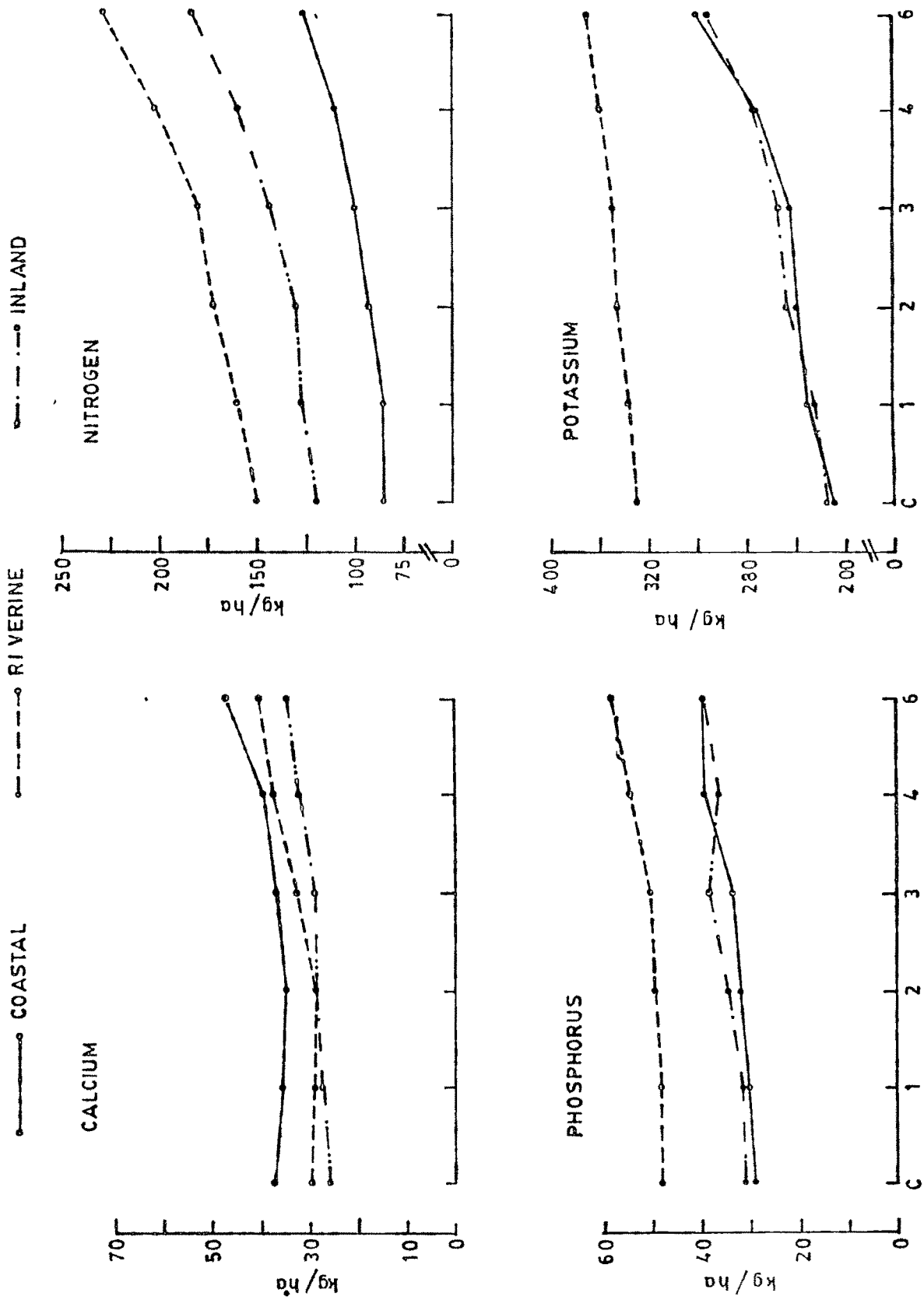


FIG 24 MINERAL CONTENT IN CASUARINA SOILS OF DIFFERENT AREA OVER YEARS

showed 17.92 kg followed by the same pattern as found in the control plot.

At the end of the second year, the top surface showed 16.9 kg followed by values ranging from 8.5 to 11.6 kg at the different levels.

The three year old plantation showed 18.1 kg calcium at the top surface, followed by 5.9 to 10.1 at different horizons.

The four year old plantation contained a slightly increased calcium status at the surface (0-20 cm) layer followed by a range of 7.5 to 10.1 kg at different horizons.

The six year old plantation exhibited a further increase in the calcium content at 23.0 kg followed by 10.6 kg at 20-40 cm layer. The deeper layers showed 6.5 to 10.1 kg (Table 46; Fig. 24-28).

Organic carbon (Per cent)

The organic carbon status was 0.83 per cent in the surface layer (0-20 cm) followed by 0.51 in the 20-49 cm layer. There was sharp reduction in the deeper layers. At the end

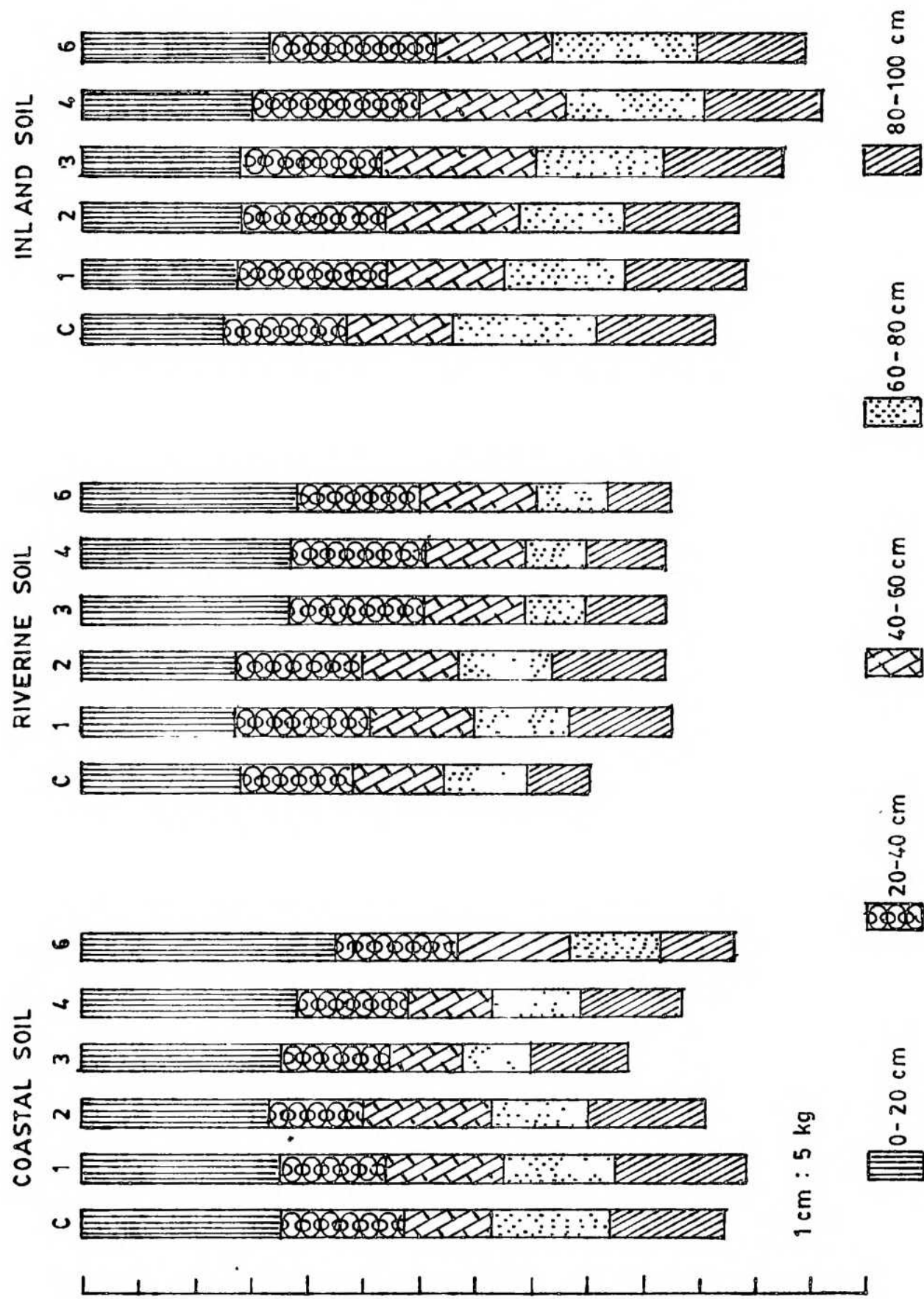


FIG.25 NUTRIENT STATUS OF CASUARINA PLANTATIONS-CALCIUM LEVELS IN SOIL PROFILE

of one year, the organic carbon (OC) status remained almost the same with 0.79 and there was no change in the deeper layers.

During the second year, there was a slight increase to raise the organic carbon to 0.88 at the surface layer. But there was no change in the deeper layers.

The three year old plantation recorded a small increase in the organic carbon at the surface layer. It showed 1.02 per cent followed by a small increase in the 20-40 cm layer where the organic carbon was 0.41 per cent.

The four year old plantation showed a value of 1.19 emphasizing the addition of organic carbon content to the soil. The second layer 20-40 cm showed a small increase to 0.42 per cent, followed by 0.19 to 0.24 per cent at the different layers.

The six year old plantation had 1.32 per cent of organic carbon, about 50 per cent increased in the surface layer. But deep below there was no appreciable change (Table 46).

Nitrogen (kg/ha)

The available nitrogen in the soil of the control

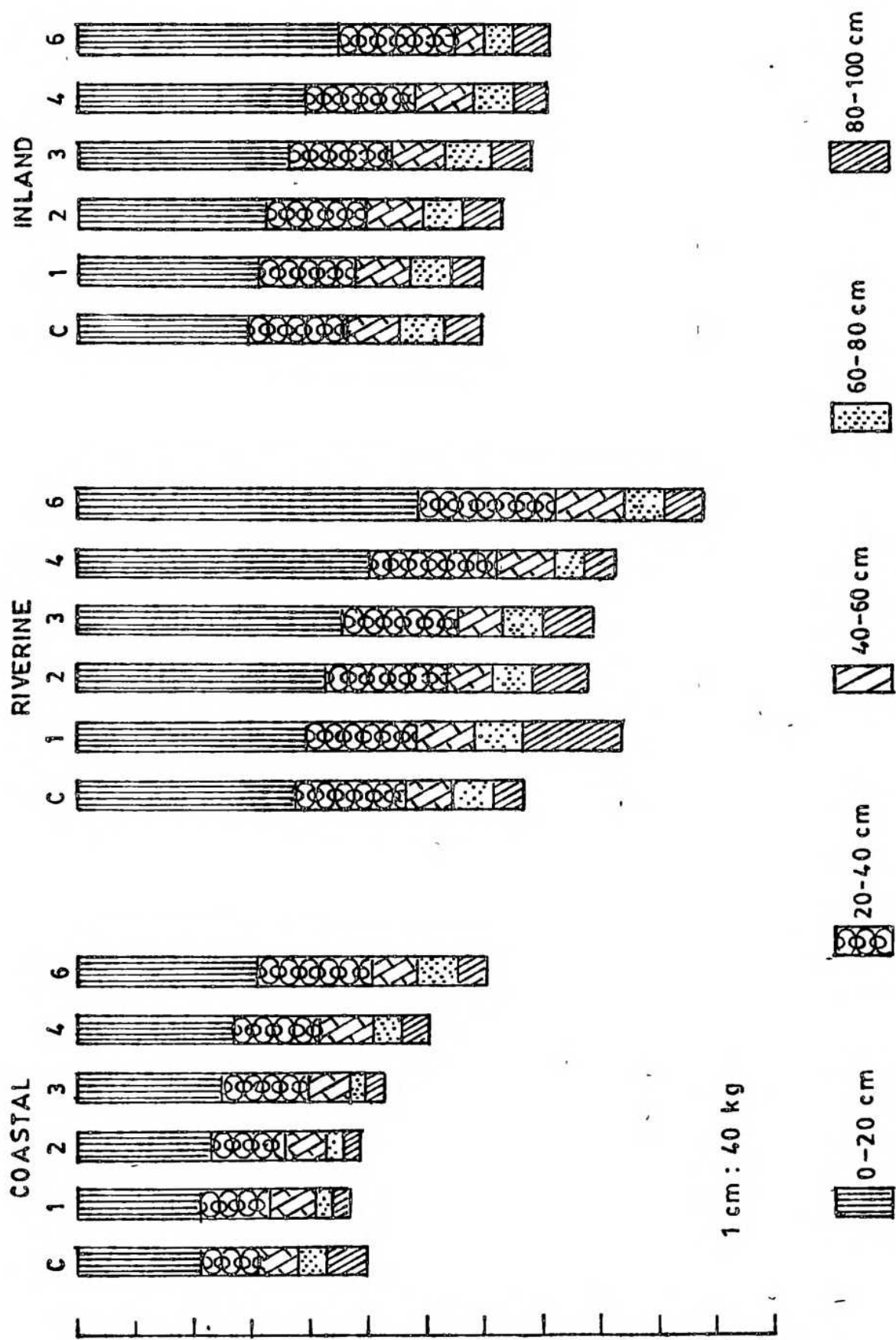


FIG. 26 NUTRIENT STATUS OF CASUARINA PLANTATIONS - NITROGEN LEVELS IN SOIL PROFILE

plot was 85.0 kg/ha at the surface layer, followed by 42.0 kg in the 20-40 cm layer. Further down, it was only 19.6 to 27.0 kg.

In the first year of the plantation the nitrogen level rose marginally to 88.8 kg/ha while there was no significant change in the deeper layers.

In the second year, the increase in the N content was also marginal, recording 92.0 kg/ha. There was a slight increase in the 20-40 cm layer, showing 52.6 kg and down below it followed the pattern of the control plot.

During the third year of the plantation, the nitrogen level rose to 99.5 kg at the 0-20 cm surface layer, followed by 59.1 kg at the 20-40 cm layer. There was no change in the deeper layers.

The four year old plantation showed 109.8 kg of nitrogen in the surface layer, followed by 62.5 kg in the 20-40 cm layer. However, the deeper layers were not influenced by the age.

The six year old plantation had 125.5 kg of nitrogen at the top surface (0-20 cm) followed by 80.6 kg in

the 20-40 cm layer. There was a slight increment of nitrogen at the 40-60 cm layer recording 32.1 kg. Otherwise there was no perceptable change in the nitrogen level. (Table 46; Fig.24-28).

Phosphorus (kg/ha)

The level of phosphorus did not change in the control, one and two year old plantations recorded between 7.3 and 7.9 kg. However, at the third year of the plantation, the surface layer showed a marginal improvement to 8.12 kg. In all the cases there was no change in its content at lower horizons.

The four year old plantation presented 9.72 kg/ha which was higher than the third year for the 0-20 cm surface layer. The 20-40 cm layer had a marginal increase upto 6.05 kg; otherwise there was no change in the P level.

However, the six year old plantation exhibited a further increment to 9.8 kg at the surface layer, followed by 7.1 in the 20-40 cm layer.

Potassium

The level of potassium varied from 210 kg/ha in the surface layer of control plot to 250 kg in the lower layers at 80-100 cm.

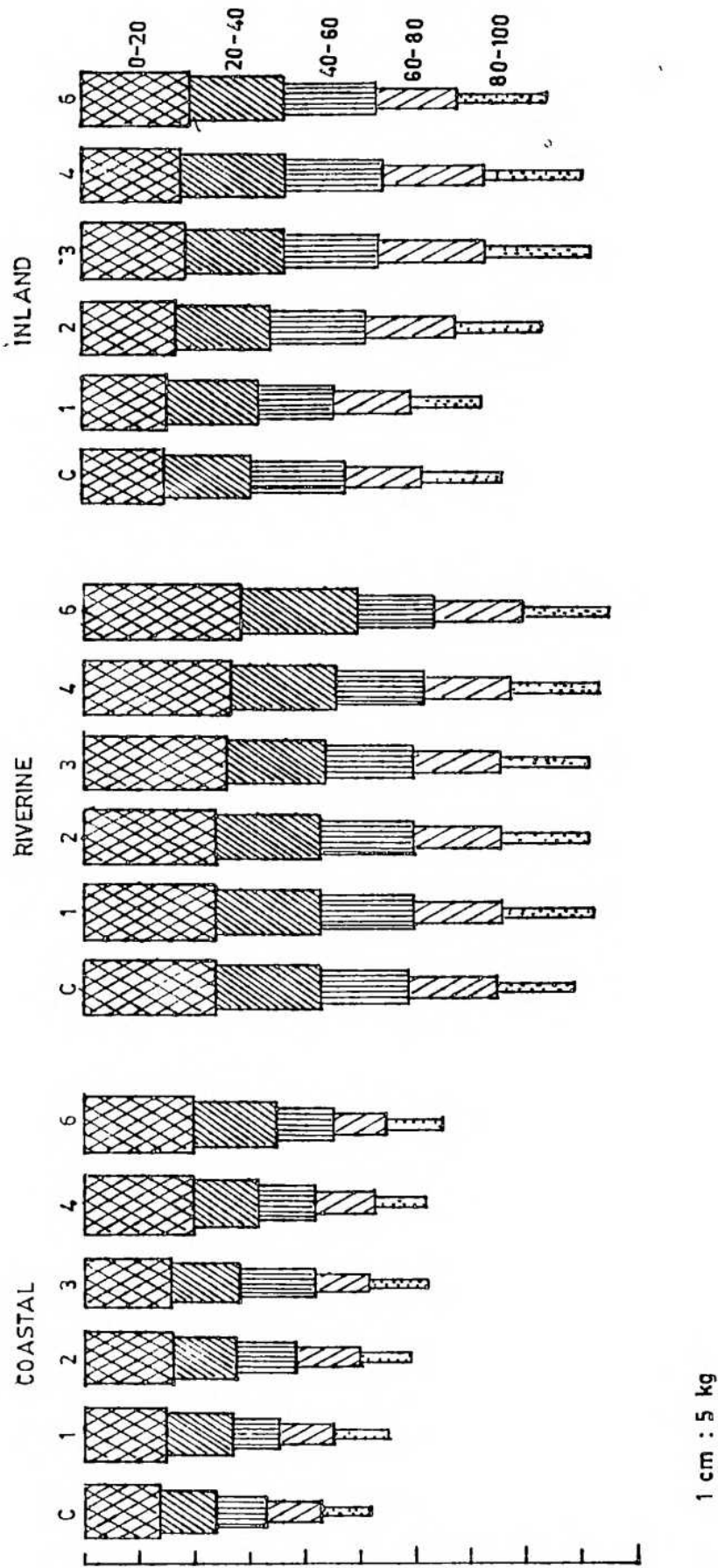


FIG. 27 NUTRIENT STATUS OF CASUARINA PLANTATIONS-PHOSPHORUS IN SOIL PROFILE

In the first year, there was no change in its level. It followed the pattern of the control plot.

In the second year, the potassium content ranged from 240 to 259 kg and it almost repeated itself in the third year. However, compared to the control plot, there was an increase of 35 kg in the surface layer and 34 kg in the 20-40 cm layer.

When the plantation was four year old, the potassium level increased to 270 kg, about 60 kg more than the control. However, there was no perceptible increase in other layers.

The six year old plantation presented further increase in the potassium content, recording 390 kg and 277 kg in the 0-20 and 20-40 cm layer respectively. Further increment was not seen in the deeper layer (Table 46; Fig.24-28).

4.5.4.2. Riverine plantation

pH

The pH of the top soil of the control plot, one year and two year old plantations remained almost similar at 7.4 to 7.3. Even the deeper layers did not show any change with all the layers reporting between 7.3 to 7.5.

The three year old plantation had a slight reduction to 6.9 in the surface (0-20 cm) layer followed by 7.1 to 7.5 in the different layers in the sub soil.

The fourth year plantation recorded a range of 7.0 to 7.3, the surface layer recording 7.1.

The six year old plantation presented further reduction in pH value at the top layer recording 6.8 followed by 6.7 in the next layer of 20-40 cm. The pH remained between 7.0 to 7.2 at the remaining layers (Table 47).

Electrical Conductivity (EC mmhos/cm²)

The control plot showed a value of 0.13 that was almost continuous in the age series, especially at the surface soil.

The first year plantation exhibited a range of 0.10-0.12, second year 0.11-0.14, third year 0.10-0.13, fourth year, 0.10-0.13 and sixth year 0.10-0.13. All of them maintained the same trend (Table 47).

Calcium content (kg/ha)

The control plot recorded a value of 14.7 kg in the surface soil followed by lower values for the deeper layers.

Table 47. Nutrient status of soil profile in riverine area - Natham Centre

Age	Soil profile cm	pH	EC mmhos/ cm ²	OC %	Available nutrients(kg/ha)			
					Ca	N	P	K
Control	0-20	7.4	0.13	2.7	14.7	152.0	11.9	367
	20-40	7.3	0.14	1.3	10.2	75.6	9.4	329
	40-60	7.5	0.14	0.4	8.3	32.6	8.3	310
	60-80	7.3	0.12	0.3	7.5	29.0	7.9	295
	80-100	7.4	0.13	0.4	5.6	19.5	7.1	310
I Year	0-20	7.4	0.12	2.8	14.2	159.0	12.1	370
	20-40	7.3	0.13	1.1	11.7	75.0	9.5	310
	40-60	7.5	0.14	0.5	9.5	37.0	8.7	295
	60-80	7.3	0.11	0.3	8.7	31.0	8.1	285
	80-100	7.3	0.10	0.2	8.5	22.0	8.4	317
II Year	0-20	7.3	0.12	2.9	13.9	173.0	12.4	385
	20-40	7.5	0.11	1.0	11.5	82.0	9.5	297
	40-60	7.4	0.14	0.6	8.7	34.0	8.5	280
	60-80	7.4	0.12	0.5	8.3	27.0	8.1	230
	80-100	7.3	0.11	0.2	9.9	30.0	8.3	272
III Year	0-20	6.9	0.13	3.1	16.1	185.0	12.9	390
	20-40	7.3	0.10	0.9	10.6	79.0	8.9	309
	40-60	7.1	0.11	0.5	10.6	31.0	7.9	310
	60-80	7.4	0.11	0.2	5.3	26.0	8.1	220
	80-100	7.5	0.12	0.3	7.2	33.0	8.3	258
IV Year	0-20	7.1	0.12	3.5	18.7	203.0	13.6	399
	20-40	7.0	0.13	1.2	11.9	87.0	9.4	335
	40-60	7.1	0.11	0.7	9.3	41.0	7.8	271
	60-80	7.2	0.10	0.3	5.6	22.0	8.4	290
	80-100	7.3	0.12	0.2	6.7	21.0	8.1	245
VI Year	0-20	6.8	0.13	3.7	19.5	236.0	14.5	410
	20-40	6.7	0.11	1.4	10.9	95.0	10.4	340
	40-60	7.1	0.12	0.5	10.3	47.0	7.1	267
	60-80	7.2	0.10	0.3	6.4	29.0	7.9	246
	80-100	7.0	0.13	0.2	5.3	22.0	8.2	305

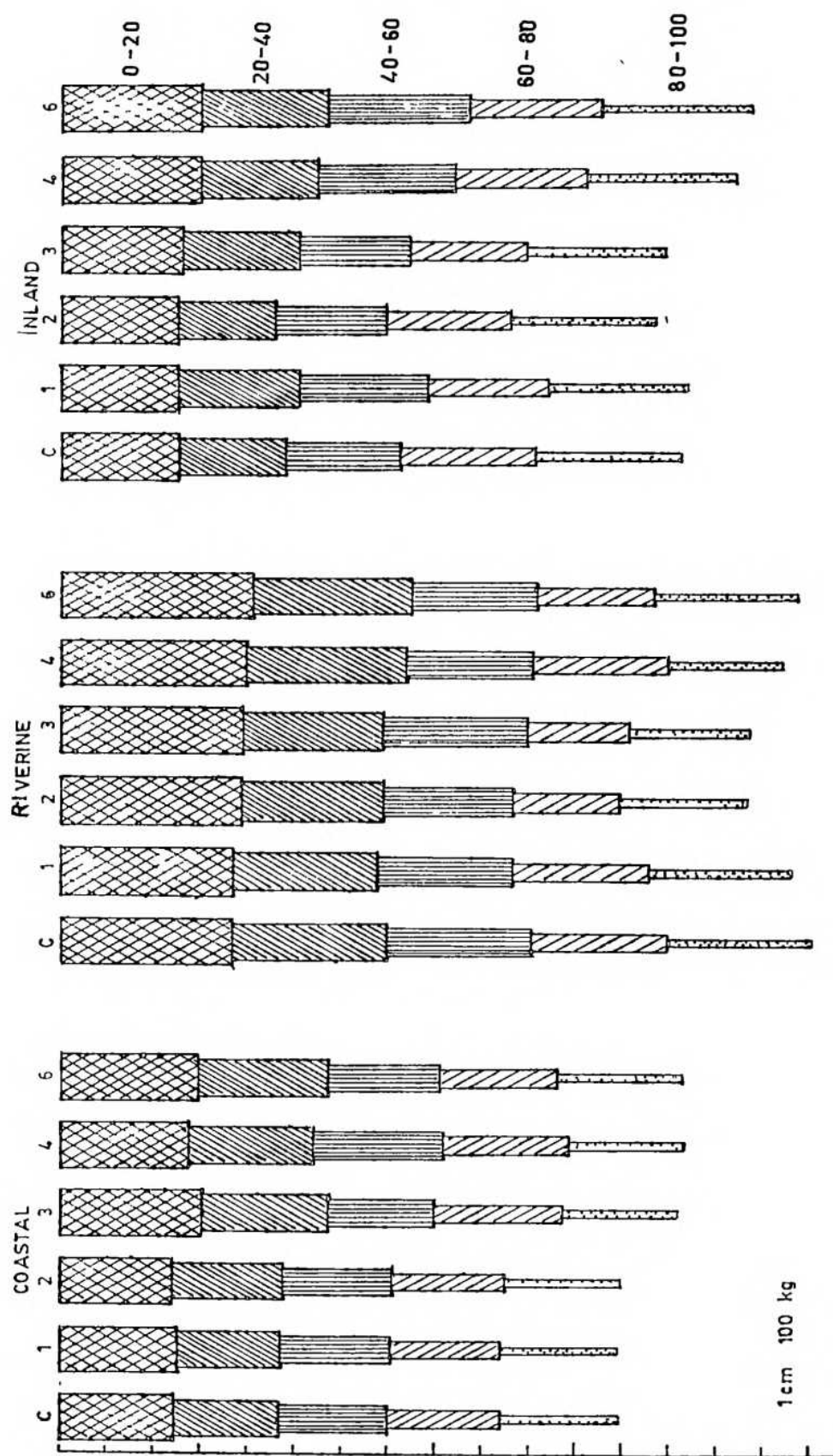


FIG 28 NUTRIENT STATUS OF CASUARINA PLANTATIONS-POTASSIUM LEVELS IN SOIL PROFILE

The calcium content was slightly high at the surface layer recording 14.2 kg in the first and 13.9 kg in the second year plantation. The deeper layers showed a progressive reduction.

The third year plantation showed a slight increase to 16.1 kg at the surface and the subsequent layer showed only 10.6. The values went down to 7.2 kg at the 80-100 cm layer.

The fourth year plantation had 18.7 kg at the 0-20 cm layer and the lower layers did not show any difference from the third year. The sixth year plantation registered an increase to 19.5 kg but the deeper layer did not show marked change (Table 47; Fig.24-28).

Organic carbon (per cent)

The organic carbon content was comparatively higher at 2.7 per cent in the control plot.

The one year old plantation recorded negligible increase in its content recording 2.8 per cent at the top surface (0-20 cm) and 1.1 per cent at the 20-40 cm layer. Further below it was between 0.2 to 0.5 per cent.

The two year old plantation showed negligible increase only, the surface recording 2.9 per cent and within the profile there was no change.

The three year old plantation registered increased organic content of 3.1 only.

The four year old plantation had further increment to 3.5 per cent followed by the next year registering 1.2 per cent which was an improvement over the previous years.

The six year old plantation registered 3.7 per cent organic carbon in the surface layer followed by 1.4 per cent in the next layer. There was no change in other layers (Table 47).

Nitrogen (kg/ha)

The available nitrogen per ha was 152.0 kg at the control plot as recorded for the surface layer. The deeper layers showed a progressive reduction from 75.0 to 19.5 kg.

The one year old plantation showed a slight increase of 7.0 kg in the surface layer. There was no change in N content change in the second layer at 20-40 cm.

The two year old plantation exhibited a further small increase taking the total to 173.0 kg, followed by an increase by 7.0 kg in the second layer at 20-40 cm. There was no change in the deeper profiles.

The three year old plantation had an added 12.0 kg of nitrogen but there was a decrease of 3.9 kg in the immediate next layer.

The four year old plantation presented 203.0 kg of N/ha in the surface layer that was 18.0 kg of increased N. The layers at 20-40 cm also showed an increase of 8.0 kg from that of previous year.

At the end of six years, the nitrogen content in the soil was 236 kg, an increment of 84 kg over that of the control. The secondary layers did not benefit to that extent from the above accretion, showing a twenty kg increase only (Table 47; Fig.24-28).

Phosphorus (kg/ha)

The phosphorus content was low at 11.9 kg/ha in the control plot. In the first year plantation it was only 12.1 kg in the surface layer followed by lesser quantities of 8.4-9.5 kg seen across the soil profile.

The two year old plantation recorded a marginal increase of 0.3 kg of P at the surface, followed by the same pattern seen in first year.

The three year old plantation did exhibit a small increment of 0.5 kg over the previous year.

The four year plantation maintained the increment to 13.6 kg while the 20-40 cm layer presented an increase of 0.5 kg only. The rest of the profile showed the earlier trend.

The six year old plantation deviated from that of the four year old to 14.5 kg at the surface layer but at the next year at 20-40 cm, the phosphorus content increased to 10.4 kg as against 9.4 kg of the control plot (Table 47; Fig.24-28).

Potassium (kg/ha)

The level of potassium was high at 367 kg in the surface layer of the control plot, followed by decreasing quantities along the profile.

In the one year old plantation, the level of potassium remained almost constant within a range of 280-370 kg.

The two year old plantation presented a range of 230-385 kg of the highest amount confined to the top layers, nearer to the surface.

The three year old plantation recorded a range of 220 to 390 at the top 0-60 cm showing high values for its content.

The four year old plantation registered an increase to 399 kg at 0-20 cm with the second layer recording 301.0 kg. The range was within 245-399 kg.

The six year old plantation had a range of 246 to 410 kg with layer 20-40 cm getting a total of 340.0 kg/ha. The further layers showed minimum increase with potassium content. (Table 47; Fig.24-28).

4.5.4.3. Inland plantation

pH

The pH of the control plot showed an acidic range of 6.3-6.7, the surface layers showing 6.5, followed by similar readings in the other levels of the profile.

One year old plantation showed 6.7 and the same was repeated in the deeper layers. The range was 6.3-6.7.

The two year old plantations also did not show any change, the pH falling between 6.3 and 6.7, the surface layer recording 6.5.

The three year old plantation maintained the above trend with the pH between 6.3 and 6.7.

The four year old plantation showed a fall in the pH, when the readings were 6.2 to 6.5. The surface layers showed values of 6.2. The six year old plantations recorded a range of 6.3 to 6.5 with the surface layer registering 6.3 (Table 48).

Electrical conductivity (EC mmhos/cm²)

The electrical conductivity of the control plot showed a range from 0.10 to 0.12. The one and two year old plantations did not show any variation. The three year old plantation showed a slight increase upto 0.14 in the 20-40 cm layer of the profile.

The four year old plantation showed a range of 0.10 to 0.12.

The six year old plantation showed a range of 0.10 to 0.14 (Table 48).

Calcium content

The calcium in the control plot registered a value

Table 48. Nutrient status of soil profile in inland areas - Virudhachalam Centre

Age	Soil Profile cm	pH	EC mmhos/ m ²	OC %	Available nutrients (kg/ha)			
					Ca	N	P	K
Control	0-20	6.5	0.11	1.1	13.0	121.6	7.7	245
	20-40	6.5	0.12	0.6	10.7	70.3	8.2	230
	40-60	6.3	0.10	0.5	9.5	36.5	9.2	256
	60-80	6.7	0.10	0.3	13.0	29.8	7.3	290
	80-100	6.4	0.11	0.4	10.6	21.5	7.0	310
I Year	0-20	6.7	0.11	1.2	14.0	127.3	7.9	250
	20-40	6.7	0.12	0.6	13.5	68.5	8.4	255
	40-60	6.3	0.11	0.5	10.6	35.9	7.2	280
	60-80	6.5	0.13	0.3	11.6	30.6	7.3	265
	80-100	6.5	0.11	0.2	10.1	20.8	6.5	302
II Year	0-20	6.5	0.13	1.1	14.5	132.8	8.5	245
	20-40	6.7	0.10	0.7	12.9	69.5	8.4	215
	40-60	6.5	0.12	0.3	12.1	39.2	9.0	235
	60-80	6.3	0.10	0.2	9.5	27.8	7.8	273
	80-100	6.4	0.09	0.2	10.1	21.5	8.1	309
III Year	0-20	6.5	0.13	1.3	14.6	147.8	9.7	261
	20-40	6.7	0.14	0.6	12.5	73.2	9.1	246
	40-60	6.5	0.12	0.5	13.8	37.8	8.3	239
	60-80	6.3	0.10	0.2	11.6	29.6	9.5	249
	80-100	6.4	0.10	0.3	10.4	25.8	9.9	295
IV Year	0-20	6.2	0.11	1.6	15.5	159.5	8.9	275
	20-40	6.5	0.12	0.9	14.8	77.8	9.4	265
	40-60	6.3	0.10	0.6	13.2	39.6	8.9	290
	60-80	6.6	0.12	0.3	12.5	27.5	8.9	287
	80-100	6.5	0.11	0.2	10.4	20.6	8.8	317
VI Year	0-20	6.3	0.14	1.7	17.0	182.7	9.9	300
	20-40	6.5	0.11	0.8	15.0	81.3	8.4	265
	40-60	6.4	0.11	0.6	10.5	21.7	8.3	295
	60-80	6.3	0.10	0.5	13.0	18.9	7.5	275
	80-100	6.5	0.12	0.2	9.6	20.5	7.8	325

of 13.0 kg and progressively lesser in deeper layers with the range of 9.5-13.0 kg.

The one year old plantation showed a range of 10.1 to 14.0, the surface layer recording 14.0 kg followed by the 20-40 cm layer registering 13.5 kg.

The two year old plantation showed a range of 9.5 to 14.5 kg with the surface layer recording 14.5 and the next, the 20-40 cm layer recording 19.9 kg.

The three year old plantations showed a range of 10.4 to 14.6 kg the top 0-20 cm layer registering the maximum, followed by the layer 40-60 cm recording the next maximum of 13.8 kg.

The four year old plantation showed a range of 10.4 to 15.5 kg with the surface 0-20 and 20-40 cm layers recording high values of 15.5 and 14.8.

The six year old plantation showed a range of 9.6-17.0 with the top 0-20 and 20-40 cm layers registering values of 14.8 and 15.5 (Table 48; Fig. 24-28).

Organic carbon (per cent)

The organic carbon content in the control plot ranged from 0.3 to 1.1 the surface layers registering high values of 1.1 and 0.6.

The one year old plantation presented the same pattern where the range was from 0.2 to 1.2.

The two year old plantation recorded similar trend with the organic carbon status level from 0.2 to 1.1 per cent in different layers.

The three year old plantation exhibited an increase in the organic carbon status recording a value of 1.3 in the top surface (0-20 cm) but the values were lower down the profile.

The four year old plantation had an increase to 1.6 per cent in its organic carbon status and the second layer at 20-40 cm also showed a slight increase to 0.9 per cent. Otherwise there was no significant change.

The six year old plantation showed further increase to 1.17 per cent at 0-20 cm layer with the next layer showing

0.8 per cent. The plantation has gained an increase of 54.54 per cent in organic carbon over a period of six years (Table 48).

Nitrogen (kg/ha)

The available nitrogen in the control plot was in the range of 21.5 to 121.6 kg/ha, the surface layer showing the maximum values.

The one year old plantation showed a slightly increased value of 20.8 to 127.3 kg, the surface layer registering the maximum. Deeper the profile was lesser the N content.

The two year old plantation showed a maximum of 132.8 kg, an increase of 11.2 kg over the control. The layers below did not gain any increase.

The three year old plantation showed a range of 25.8 to 147.8 kg with the deeper layers maintaining small increment. The 20-40 cm layer showed an increase to 73.2 kg against 70.3 kg of the control.

The four year old plantation showed a range from 20.6 to 159.5 kg the increments confined to the 0-20 to 20-40 c

layer. The 20-40 cm layer registered an increase of 4.6 kg over that of the three year plantation.

The six year old plantation registered a range from 20.5 to 182.7 kg with the bulk of the increment going to the top layer. The layer at 20-40 cm registered an increase of 11.3 kg over the control (Table 48; Fig.24-28).

Phosphorus (kg/ha)

The level of available phosphorus in the inland area was generally low. The control plot showed only 7.7 kg in the surface layer and almost similar trend at the other levels of the profile.

The one year old plantation did not show any marked improvement over the control; a marginal increment of 0.2 kg was recorded.

The two year old plantation showed a marked improvement to 8.5 kg at the surface layer with a range of 8.1 to 9.0, but the high value was recorded by the 40-60 cm layer in the profile.

The three year old plantation recorded a range from 8.3 to 9.9, the highest value recorded by the deepest

layer (80-100 cm). The surface layer (0-20 cm) showed 9.7 kg/ha.

The four year old plantation showed a decrease in the phosphorus level in the surface and with a range of 8.3 to 9.9.

The six year old plantation registered a maximum of 9.9 kg at the surface layer followed by 8.4 in the 20-40 cm layer. The rest showed lesser value (Table 48; Fig. 24-28).

Potassium (kg/ha)

The level of available potassium in the soil ranged from 215 to 310 kg/ha in the control plot.

One year old plantations showed an average of 280-302 kg/ha with the value 230 confined to the surface layer.

In the two year old plantation, the range was from 245 to 309 with the surface layer (0-20 cm) recording only 245 kg. The deepest layer showed high values also.

The three year old plantation exhibited a range from 251 to 295 kg with the surface 0-20 cm layer containing 251 kg and followed by 20-40 cm with 246 kg.

The four year old plantation showed a greater range of 275 to 315 kg with the top layer recording 275 kg and the next year at 20-40 cm recording 265 kg. The deeper layer 80-100 cm recorded 317 kg.

The six year old plantation showed a range of 310 to 325 kg. The surface layer exhibited 310 kg while the 20-40 cm layer showed only 265 kg (Table 48; Fig. 24-28).

4.5.5. Annual Nutrient Return

The mineral contents in the standing biomass and litter components were estimated to quantify the nutrient available for cycling. The amount of nutrients in the coastal area plantation was considerably lesser than that of riverine areas. However, the nutrients in the standing crop were Ca 1100.6, Mg 255.9, Nitrogen 557.0, Phosphorus 38.1 and Potassium 209.6 kg/ha for coastal area. In the riverine areas it was Ca 1844.5, Mg 606.2, Nitrogen 1095.3, Phosphorus 65.3 and Potassium 410.5 kg/ha. The litter components yielded 113.1 kg calcium, 17.7 kg magnesium, 78.9 kg nitrogen, 6.2 kg phosphorus and 26.1 kg potassium for coastal area while it rose to 163.9, 39.1, 144.9, 12.6 and 46.8 kg per ha in riverine areas.

The annual uptake had been substantial with coastal area recording 296.5 kg calcium, 60.3 kg magnesium,

171.7 kg nitrogen 6.2 kg of phosphorus and 26.1 kg of potassium, while riverine areas absorbed almost double that of coastal area with 471.3 kg calcium, 140.1 kg magnesium, 327.4 kg nitrogen 23.4 kg of phosphorus and 115.1 kg of potassium (Table 49).

4.5.6. Net Reproductive Effort

The production of cones ranged from 1.9 to 10.5 kg in the coastal, 2.1 to 10.9 kg in riverine and 1.9 to 3.7 kg in inland areas showing a mean of 4.6, 5.5 and 3.0 kg respectively. The mean of total dry matter for the respective tree sources were 50.9, 83.2 and 32.7 kg. A conversion of the reproductive effort from the total assimilatory effort indicated a range of percentage as 9.03 for coastal, 6.61 for riverine and 9.17 for inland plantations.

The production of cones with each ecosystem on a per tree basis was very variable as indicated by the high cv of 50.7 and 54.9 per cent for coastal and riverine plantation and limited to 15.1 per cent in inland plantation. The average seed production from each plantation, on a per tree basis, ranged from 77.7 g for coastal, 123.6 g for riverine and 52.3 g for inland plantations.

In all the situations, the total dry weight and needle weight showed high positive correlation both between cone and seed production (Table 50).

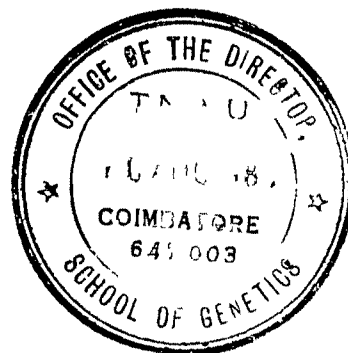
Table 49. Mineral contents in biomass and litter components, annual uptake, retention and release of nutrients through litter-fall(kg/ha)

Area	Age	Component	Nutrients				
			Ca	Mg	N	P	K
Coastal	6 Yr above ground biomass	Stem	427.1	170.8	165.5	7.4	80.0
		Bark	131.9	12.2	25.8	0.4	13.2
		Branch	127.0	26.3	70.3	1.0	43.9
		Needle	414.6	46.6	295.4	29.3	72.5
		Total	1100.6	255.9	557.0	38.1	209.6
	Litter	Needle	83.0	9.4	59.1	5.9	14.5
		Cone	5.6	2.6	5.9	0.1	2.9
		Infl.	0.6	0.4	0.7	tr	0.4
		Twig	23.9	4.9	13.2	0.2	8.3
		Total	113.1	17.7	78.9	6.2	26.1
		Uptake	296.5	60.3	171.7	12.5	61.0
		Retained	183.4	42.6	92.8	6.3	34.9
		Released	113.1	17.7	78.9	6.2	26.1
Riverine	6 Yr above ground biomass	Stem	877.1	409.3	438.5	9.7	185.1
		Bark	256.1	25.7	51.4	0.8	27.4
		Branch	180.7	58.7	82.8	1.8	58.7
		Needle	530.6	112.5	522.6	53.0	139.3
		Total	1844.5	606.2	1095.3	65.3	410.5
	Litter	Needle	121.1	25.7	119.3	12.2	31.8
		Cone	7.6	1.8	6.1	0.1	3.4
		Infl.	0.6	0.4	0.8	tr	0.4
		Twig	34.5	11.2	18.7	0.3	11.2
		Total	163.9	39.1	144.9	12.6	46.8
		Uptake	471.3	140.1	327.4	23.4	115.1
		Retained	307.4	101.0	182.5	10.8	68.3
		Released	163.9	39.1	144.9	12.5	46.8

Table 50. Net Reproductive Effort (NRE) in three ecosystems

S. No.	Coastal			Riverine			Inland					
	Total weight kg	Needle Cone weight kg	Seed weight g	Total weight kg	Needle Cone weight kg	Seed weight g	Total weight kg	Needle Cone weight kg	Seed weight g			
1.	13.9	2.2	1.9	28.5	74.7	14.0	5.1	109.7	22.8	3.6	1.9	32.2
2.	16.2	2.7	2.1	33.6	51.9	10.6	3.1	73.5	26.9	3.7	2.7	49.5
3.	35.6	6.9	4.4	57.3	78.5	15.5	4.7	96.5	35.6	5.4	3.1	59.7
4.	53.1	9.2	4.1	73.8	94.7	13.2	5.7	111.4	27.0	3.5	2.9	52.0
5.	42.6	8.2	5.1	102.0	121.8	16.5	10.7	267.3	26.9	3.9	3.2	49.3
6.	56.9	9.5	3.0	53.4	50.9	8.2	2.1	49.5	34.9	4.0	3.5	54.6
7.	63.3	9.0	5.3	103.3	72.2	10.0	5.0	104.8	38.8	5.5	3.7	59.7
8.	105.6	18.0	10.5	173.2	89.2	5.8	2.7	60.2	38.6	4.5	3.2	57.2
9.	82.7	13.5	6.1	112.2	115.2	16.5	10.9	239.7	34.3	4.8	3.4	60.1
10.	39.3	6.8	3.7	77.7	-	-	-	-	41.8	3.9	2.9	49.3
$\bar{x}$	50.9	8.6	4.6	81.5	83.2	12.2	5.5	123.6	32.7	4.3	3.0	52.3
cv	52.7	51.4	50.7	50.2	26.0	29.3	54.9	58.8	18.5	16.1	15.6	15.1
NRE	9.03			6.61			9.17					
'r' value	Total weight to cone production			0.8740			0.6404					
	Needle weight to cone production			0.8048			0.6136					

DISCUSSION



V. DISCUSSION

Perennial species show wide variation in several of their morphological and physiological characteristics along the gradient of their distribution. The prevailing geographic and edaphic situations have been instrumental in delineating ecotypes. Several documentations have appeared in species like Acacia nilotica (Oboho and Ali, 1985), Fraxinus americana (Daniels, 1978), Casuarina glauca and C. cunninghamiana, (El-Lekany and Shepherd, 1983) and Pinus halepensis (Falusi et al., 1983) on the seed and seedling behaviour in relation to the sources, seed weight and germination vigour.

5.1. Seed size : influence on germination and vigour

The 100-seed weight of seeds of C. equisetifolia from the four ecosystems studied in the present investigation indicated distinct positive association with the germination per cent, speed of germination and seedling height. It showed significant positive correlation with the above three characters in all the four sources of collection. The mean 100-seed weight ranged from 0.07 g (Virudhachalam), to 0.20 g (Natham). Pathak and Gupta (1985) showed that the seedlings from large seeds in Hardwickia binata had greater growth rate as compared to those from small ones. On the contrary, Oboho

and Ali (1985) reported that germination did not vary with seed weight but seedling height and appearance of leaflets did, show highest for the high seed weight and lowest for the low seed weight class. Pathak et al. (1980) were of the opinion that seedling height in Acacia nilotica followed the pattern of seed weight and tallest plants were obtained from the largest seeds. In Pinus hartwegii, large and medium seeds as opposed to small seeds showed highest germination (Niembro et al., 1978).

Increased germination per cent and vigour in the riverine sources could be explained owing to, that germination responses were strongly associated with seed development and size which were selected favourably under natural conditions. The presence of availability of assured moisture in the riverine areas where these collections were made could have favourably contributed as a selection force effective on seed weight (Schimpf., 1977). The advantage conferred by larger seed was its ability to emerge from greater depths (Black, 1956) or through deeper litter or vegetation (Gross and Werner 1982). Wittington (1973) was of the opinion that seed germination characters were under genetic control and that the pattern of behaviour in cultivated or wild species is likely to have resulted from selection for seed size, vigour and seedling growth.

It is to be noted that concomitant to the increased seed weight, there was an increased germination per cent, speed

of germination and seedling vigour in *Casuarina* as expressed in terms of the height of the seedlings grown-under uniform conditions. The highly variable germination per cent, vigour and seedling growth height were found within and between the four collections of *Casuarina*. Jambulingam and Surendran (1988) reported germination, seedling height and mean number of branches were influenced by different accessions of *Gliricidia sepium* from several sites of their natural range of distribution.

The coefficient of variation for seed weight was almost similar in all the locations but germination per cent was highly variable between the sources. The inland source combination showed a very high cv of 63.15 (mean 28.40) and Virudhachalam^{Source}/55.53 (mean 25.41), while coastal (Marakkanam) and riverine (Natham) sources showed a cv of 35.36 and 39.66 and mean of 37.72 and 41.40 respectively for germination.

The seedling height growth showed high differences between the four sources; highest being in riverine (Natham) source. But variation within source was nearly uniform in all the cases. The increased growth rate of seedlings was characteristic of the riverine area where the plants found their fullest expression. Barring the germination per cent, the individuals of Natham had shown that selection for fast

growth would be productive and it may be useful if many stands were sampled within the specific chosen areas and selection is exercised over generations. Steiner (1983) had reported similar zones of fast growth rate for Green Ash (Fraxinus pennsylvanica) extending from West Central Illinois to Eastern Nebraska for effective seed collection.

Chauhan and Raina (1980) found a positive correlation in chir pine (Pinus roxburghii) between germination vigour and seedling dry weight with seed size (weight). Gosh showed grading of seeds of Pinus roxburghii had a positive influence on growth of the seedlings. Daniels (1978) recorded significant differences in the size of the fruits and seeds obtained from different latitudes and longitudes along the growing range of white ash (Fraxinus americana). Shivkumar and Banerjee (1986) showed that 100 seed weight significantly differed from one another among nine provenances of A. nilotica collected across several latitudes in India. There were significant differences between the height of plants at age of one year among the several provenances tested by them. Mathur et al (1984) had also shown variation in seed germination among different sources of A. nilotica ssp indica.

The growth of seedlings from large and heavy seeds is explained not only by the large reserve of nutritional matter contained in them but also by their bio-chemical

endowments. Translocation of reserves from endosperm to embryo proceeds differently in large and small seeds. Better filled, large seeds of Pinus thunbergii transformed more nitrogen from the endosperm to the embryo after sowing than the small seeds did (Katsuka 1974). Larger seeds may be able to emerge from greater depth (Black, 1956) or through deeper litter or vegetation (Gross and Werner, 1982).

Seed vigour estimates from germination test parameters had long been a standard method of assessing seed quality. Per cent germination is the primary parameter of germination testing for seeds of high quality and little dormancy. In Casuarina equisetifolia per cent germination was significantly correlated with seedling height in all the four locations (Table 5). The measure of germination rate, as revealed by speed of germination, either alone or in combination with another parameter like height of seedling is a better indicator of seed quality. Losses of seed quality are first observed as reductions in germination rate. The major effect of stress environments for germination is a decrease in seedling emergence rates in the nursery. Further, more seedlots that exhibit faster germination rates will produce more uniform emergence in the nursery beds (Bonner, 1986). Wasser (1978) had shown that increasing the rate of emergence uniformly can decrease the cull per cent in loblolly seedlings. Barnett and

McLemore (1984) had suggested that laboratory germination percentages were still the best predictors of seedling production. Considering all the above, the increased germination per cent now obtained in the seed source from riverine location is an indicator of quality for nursery production and seed collection, as against other locations.

When comparatively a better/favourable ecology is available for plant productivity, then selection of genotypes should be at multistages or across the growth phases so that the selection response will be maximum at each stage, thereby cumulatively conferring better advantage to the tree species when it reaches the felling stage. Evidently the seedling stage is the initial stage for selection and the present study indicated the scope for genetic selection with stability at seedling stage. It may be worthwhile to evolve selection indices at seedling stage so that it will have its application in casuarina improvement.

5.2. Optimum age for harvesting cones

It is usual for a casuarina to produce female cone by about 10 or 12 months after planting but the age at which cones are more productive and the seeds more viable for release of seeds has not been studied in detail and determined.

Considerable research has been done in temperate species like Pinus taeda and P. elliotti. Schmidting (1971) reported that Pinus taeda were sexually mature at three to four years in the field and bore both male and female flowers. It was customary to expect flowering in the field from trees of seedling origin while they were 10-15 years of age (Barber and Lorman 1964) but grafted, air layered and rooted cuttings produced flowering very early at 2 or 3 years of age. The significant difference in germination between seeds of four age series in Casuarina reported here indicated the desirability of collecting seeds from the V or VI year of the plantation for all the three locations. This could be followed as an yardstick for procuring quality seeds for large scale nurseries or in orchard management.

5.3. Ranking seed collection areas

Locations that showed high values for parameters like seed weight, germination, germination speed, seedling vigour and related characters were assigned grades ranging from 1 (very low) to 4 (very good). There were nine traits under discussion and so the maximum grades of the entries in a location could be upto 36. Under this grading, maximum grade (36 marks) was obtained by the riverine centre Natham, followed by coastal centre (Marakkanam) with a score of 24. The minimum score of 15.0 recorded by Virudhachalam and

Coimbatore which was much lower than the mean score of 22.50 over locations when the seeds from the four different locations were grown at a common location at Coimbatore.

The locations showing scores of less than the mean score of 22.50 were taken for consideration and the location that had the least score in the group (i.e. below 22.5 marks) was examined. The corresponding parameter showing lowest scores in the selected or identified location was decided as the parameter requiring attention for further development. For example, the total scores of the third location (Coimbatore) was 15. This total marks of 15 obtained was due to the scores distributed as shown in Table 5d and 1st, 3rd, 4th and 5th parameters exhibited the minimum scores. Therefore the above parameters needed further investigation and attention for improvement. Most of the characters evaluated were also highly influenced by the environment in different locations. The environments at inland ecosystem represented by Coimbatore and Virudhechalam are not conducive for better expression of these traits. It is possible that by manipulating environmental and managerial efficiency and seedling genotypes, further improvement could be obtained in the case of the location scoring lower scores. However, with the existing management aspects, the locations in riverine and the coastal areas had provided comparatively efficient

Table 51. Grading the locations based on germination traits

S.No.	Characters	Grading Location**	Points/Location*			
			1	2	3	4
1.	100 seed weight	R M C V	4	3	2	1
2.	Germination	R M C V	4	3	2	1
3.	Germination Vigour	R M C V	4	3	2	1
4.	Seedling height	R C M V	4	2	3	1
5.	Parent dbh	R M V C	4	3	1	2
6.	Parent dbh	R V C M	4	1	2	3
7.	Cone length	R M V C	4	3	1	2
8.	Cone width	R M V C	4	3	1	2
9.	No.of ovules/cone	R M V C	4	3	1	2
Total			36	24	15	15 : 22.50
Percent			100.0	66.6	41.6	41.6

* Points per location:

1 : 4

2 : 3

3 : 2

4 : 1

** Locations

R (Riverine)

M (Coastal)

C (Inland)

V (Inland)

- Natham

- Marakkanam

- Coimbatore

- Virudhachalam

seeds. This aspect would be essential for procurement in silvicultural management of the species and possibly selection for improvement in performance may be practised.

The present investigation had taken into account the variations in cone characteristics, seed weight and seedling related characteristics. It indicated that the location of collection had a significant influence over the seed quality characters and this could be effectively combined with efficient seedling selection for better stand and performance at initial stages and increased apportionment of biomass to the tree trunk. It will be a desired direction for evaluation study of the further performance of the selection in these two locations till the felling stage.

5.4. Stability parameters

Selection of best performing individuals or families is based on estimating the progeny performance and the stability of their performance over environments or across growth stages in an environment. Conventional testing does not provide adequate insight for measurement of stability despite the information on genotype x environment interaction. Hence estimation stability of genetic traits over several environments (localities) and time, had been brought about by several authors. Eberhart and Russel (1966) elaborated a

model for measuring the varietal adaptation based on the regression technique for measuring the stability of genotypes. They defined a stable genotype as one which showed a high mean yield, regression coefficient (b) around unity and deviation from regression near to zero. Langer et al (1979) indicated that the regression coefficient was a measure of response to varying environments.

The responsiveness of the tree seedlings to grow over the three growth phases (six, nine and twelve months) for three plant traits viz., height, diameter at collar and number of branches had indicated some of the families to be distinctly consistent for their performance, especially from riverine sources (Family 11, 12, 13, 14 and 16) and coastal source (Family 6). The three parameters of stability viz., the high mean performance, regression coefficient ('b') and mean square deviation ($\bar{S}d^2$) were considered together for the three characters and presented in Table 16-18 and Fig.15-17 Families 6 and 16 for plant height 6, 11, 12, 13, 14 and 16 for diameter at collar and number of branches (Table 19; Fig. 15 + 17) recorded high mean values. The highest mean values obtained by Family 16 was followed by Family 6 for all the traits. It is also to be noted that among the eight families (Families 6, 12, 13, 14, 15, 16, 18 and 19) that showed more than the mean + 1 SED, seven had originated from the riverine areas. Ten families (6, 11, 12, 13, 14, 15, 16, 17, 18 and

19) had shown values over mean + 1 SED for diameter at collar, followed by ten families (11, 12, 13, 14, 15, 16, 17, 18, 24 and 27) that had shown high branch number over the mean + 1 SED.

Families that showed high mean (overall mean + 1 SED) could be considered for characterization for further selection/improvement since in tree crops the basis of selection usually adopted is mean plus one standard error (Cavalcanti and Gurgel, 1973).

The D^2 analysis also gave the extent of divergence based on the maximum variation in the families and will support the selection of clusters of families. Among the 8 clusters (I to VIII) identified, cluster V showed the best growth for height, diameter and number of branches and included two families. The two families F_6 and F_{16} that constituted the cluster V drawn from coastal and riverine areas would be the most desirable for consideration in establishing seed stands for generating seed sources for future seedling production and also to develop stands.

5.5. Genetic parameters

The knowledge on the nature and extent of variation available within a population in its natural range of

distribution is the most desired criterion to be considered before involving in tree improvement programmes and for identifying genetically desirable and acceptable sources for selection.

Genotypic and phenotypic variances, genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV), heritability, genetic advance, and genetic advance as per cent of mean were estimated for the three economic traits at three of the growth stages namely six, nine and twelve months for all the three sources of families (Table 20) from coastal, riverine and inland areas. Variance components are used for estimating heritability by equating the statistical components of variance to their genetic variance, non-additive genetic variance and phenotypic variance (Zobel and Talbert 1984). Expression of quantitative attributes which are under polygenic control is largely influenced by the environment. Differences due to the environment will obscure differences due to genotypes. The greater the proportion of the total variability that is due to the environment, the more difficult will it be to select for inherited characters. On the other hand, if environmental variability is small, selection will be efficient and direct. This emphasised the need for partitioning the overall variance into heritable and non-heritable components.

Burton (1952) suggested that the amount of progress to be expected by a selection programme, can be precisely estimated by a combined study of the genetic co-efficient of variability and heritability. Lorman (1976) reported that heritability estimates have an important place in tree breeding. Heritability values expressed the proportion of variation in the population that is attributable to genetic differences among the individuals. It is therefore a ratio indicating the degree to which parents pass their characteristics along to their offspring. The heritability used in this study is broad sense heritability, defined as the ratio of total genetic variation in a population to the phenotypic variation. The heritability estimates ranged from 0 to 1 (Zobel and Talbert 1984). The heritability estimates tend to be higher when the particular population is grown under controlled conditions where the environmental variations have been less compared to an open field. The heritability values of a given characteristic in a population can often change with age (Namkoong et al., 1972; Namkoong and Conkle 1976). Schmidting (1983) reported this as male flowering increased with age, the heritability also increased in Pinus taeda.

The heritability estimates for height and diameter at collar have been large for coastal and inland sources as

compared to the riverine source at six month stage. However, for number of branches, riverine and inland sources showed high values but coastal sources exhibited low estimates. The same trend is followed through the nine month and twelve month growth phases also. Similar findings have been made for Eucalyptus tereticornis (Krishnaswamy et al., 1982 and Surendran 1982). High heritability estimates for traits in the first and second year were obtained for Populus deltoides by Nelson and Tauer (1987). The consistency in heritability estimates over the three growth stages indicated that over the time stages, genetic factors became more dominant than site factors in determining growth rate (Ying and Bagley 1976).

The effectiveness of selection for any character depends not only on the character expression but also on the availability of genetic variability in a particular environment, and in the magnitude of the heritability. The improvement that can potentially be made from selection for a characteristic was a function of the heritability of trait and the variation for the trait that existed in the population. Plant height, diameter at collar and number of branches in the coastal and inland sources showed high values of genetic advance and heritability indicating that heritability for these characters is largely due to additive gene effects.

Highest GCV of 18.55 for plant height for families from coastal area, 18.25 for plant diameter at collar from coastal area and 23.96 for number of branches from inland area have been reported for families of six month growth. The same traits showed high GCV values of 16.94, 18.77 and 19.91 respectively at nine month stage. Almost similar trend was encountered for the twelve month stage. The phenotypic coefficient of variability followed identical trend. It should also be noted that GCV for the traits in inland selections had been almost equal to the GCV for coastal selections at all the three stages of growth. However the GCV for the riverine selections had been low and consistent from the first to the third phase indicating a stable population little influenced by growth period. The fall of GCV estimates from the first growth phase to the third phase in coastal area and inland indicated an impact of environment on growth. The minimum difference between PCV and GCV for the different traits indicated minimum influence of environment in the expression of the populations under study. The differences between PCV and GCV were in general rather low and they would enable to make effective selection especially for the traits height and diameter.

5.6 Exploiting variation for tree improvement

Seedlings from varying ecosystems or geographical areas often display characteristic pattern of shoot growth

when grown under a common environment. Analysis of variation in growth related traits of some species might indicate the adaptive differentiation into distinct population.

Abiotic factors like temperature and nutrients in the soil also exert strong selection pressures on tree population. Environmental factors that change over dramatically over short distances also tend to develop discrete populations adapted to such environments and behave differently, indicating great variations in growth characters in seeds for the seedlots of the areas under study. The continued observation over time had indicated that the environmental variations between the areas had been minimum.

The open pollinated families that have been evaluated through their progeny performance indicated the possibility of using some of the elite families for developing clones or progenies or populations of superior performers. The genotypic value of the above average trees can be determined through open pollinated tests and best trees can either be grafted or vegetatively multiplied for clonal seed orchards considering the high degree of success this species had in vegetative reproduction upto 90 per cent, (Somasundaram and Jagadees 1977), it is amenable to develop clonal seed orchards through selective clones. An open pollinated breeding

scheme offers the opportunity for genetic gains at a cost that is generally lower than a controlled pollinated programme (Purnell and Kellison 1983).

The problem of dioecy is likely to interfere in the orchard design and seed production. Male and female trees should be positioned carefully for maximum pollination efficiency. More female gametes would be needed than the male gametes. Males may be restricted to best 4-5 clones. By using rooted cuttings instead of seed orchard seedlings, greater genetic improvement can be attained for commercial plantation.

The greater advantage of using clonal plantations at the present stage of development of forest tree improvement is the ability to effect more rapid and greater improvement in genetic quality of planting stock than could be achieved by any other breeding method during the first cycle of a breeding programme. The best way to capture non-additive, in addition to additive genetic variance, is through vegetative propagation (Shelbourne 1969). However where seeds can be produced with relative ^{ease} use, as in Casuarina, adopting sexual methods can be more effective since gains from cycles of selection will be cumulative in simple recurrent selection. It offers that gains can be made by selection from an improved population from selection and genetic recombinations. With a species

that falls under short rotation, recurrent selection could be a better tool in the long run even though for a short term program, the clonal orchards can offer immediate supply of seeds of improved trees.

5.7. Biomass and its components

The influence of site had expressed effective variation on the growth of the species in the different centres as reflected in the biomass accumulation. While the seedling material being the same source, its performance was highly variable as influenced by the site, environmental factors, soil type and climatic conditions. Among the three centres viz., riverine, inland and coastal, the superiority of the riverine centre was reflected on the consistent increase in all characters and particularly so with regard to stem weight, branch weight, needle weight and root weight when compared to the inland centre. The high per cent increase in all these attributes was found in roots that showed 74.08, 203.38 and 117.76 per cent increase respectively in three age phases. The faster and efficient rate of root development could be influential in absorbing maximum nutrients and bringing about increased biomass.

Binkley (1986) was of the opinion that low nutrient availability required increased root system for

mobilising the nutrients by mass flow and diffusion. The efficient allocation of resources for maximum nutrient uptake involved production of roots of the smallest possible diameter. This allowed exploitation of the maximum soil volume^m by each gram of tissues. Roots exploit soil to a distance of about 0.1 to 15 mm from their surface (Barber 1984) and so the logical solution to low nutrient availability lies in the development of more extensive root systems. Yadav (1983) generalised that the growth performance of the casuarina plantation on the inland areas is inferior to that obtained in the coastal areas despite the fact that casuarina can grow on the red and lateritic soils.

The increase in productivity over the three age series was influenced variably by the areas of culture. Among the three areas, riverine centre had shown consistently maximum growth for all the traits under study while the other two centres, in the order of coastal and inland, had expressed biomass at relative rates consistent with nutrient status of the environment.

The coastal and riverine locations have shown 36.70 and 89.50 per cent increased growth for height over inland in the first year. The trend was maintained in the third year with 61.89 and 161.32 per cent over inland. These

values are almost double that of the first year's growth performance between the three locations. The differences indicated the early fast rate of growth of coastal and riverine locations over inland. (Table 37).

In the sixth year, the increment had been 3.82 and 47.33 per cent over inland, considerably lesser than the previous years, indicating a decline in rate of growth for riverine and coastal sources. Apparently, it would have reached a lag phase, if the fast growth in the third year is considered exponential. Alternatively, the inland location should be considered active during the third and sixth year.

The growth performance between coastal and riverine locations indicated an increase of 38.61, 61.42 and 41.90 per cent by the latter over the former, at the first, third and sixth year, the active phase being between the first and third year rather than the third and sixth year (Table 37).

The coastal and riverine centres showed an increase of 27.53 and 78.26 per cent in the first year, 22.56 and 107.56 per cent in the third year, and 8.64 and 38.12 per cent for diameter at collar during the sixth year over inland centre. The spurt in the diameter growth by riverine in the first and third year had slowed down in the

sixth year while coastal centre had shown gradual increase in the first two stages but slowed down in the third stage (sixth year). The pattern simulated that of height growth. Between coastal and riverine centres, the increased trend maintained by riverine area was 39.87, 69.75 and 16.61 per cent for the three growth phases, indicating a decline of growth during the sixth year stage (Table 37).

The measurements recorded for diameter at breast height for the third and sixth year indicated an increase of 21.34 and 134.75 per cent by coastal and riverine centres over inland. During the sixth year, the increase had declined to 13.69 and 49.63 per cent respectively. Between the riverine and coastal centres, the increase shown by riverine over coastal was 93.46 and 31.87 per cent for the two ages (Table 37).

The measurements recorded in respect of bark weight for the three centres indicated the superiority of riverine and coastal centres showing 125.13 and 56.98 per cent over inland while riverine registered 43.41 per cent increase over coastal centre.

The coastal and riverine centres registered an increase of 25.75 and 103.03 per cent over inland at the

third year followed by 90.54 and 131.41 per cent at the sixth year with respect to branch weight. It is interesting that while the coastal and riverine centres had shown a decline in the productivity of components like height, diameter at collar and at breast height, they had showed a continuous, increasing trend with regard to branch weight. This may not represent additional number of branches but increased secondary growth over the third year to sixth year period. It may also indicate that the twig and branch fall (caused by abscission) was relatively lower in these two centres than the inland centre (Table 37).

The riverine centre showed an increase of 61.44 per cent over coastal in the third year but at the sixth year, the increase was 21.45 per cent indicating (i) the increased branch production by coastal and (ii) decreased production by riverine centre.

The production of needle by inland, coastal and riverine centres had been consistently on the increase in all the three growth stages (years). The increase of 18.17 and 86.43 per cent by coastal and riverine centres over inland was followed respectively at 60.00 and 132.80 per cent in the third year and 111.67 and 157.11 per cent in the sixth year, indicating that a progressive increase in output of the

needle had been a notable feature of the trees in all the centres. The production of needle indicated a different rate of development, while there was a decline in the per cent growth of traits like height, diameter, stem weight and root weight. The consistency in the increment on needle weight for all the centres over the growth periods is a valuable factor in the development of the tree.

However, the differences in per cent increase between the riverine and coastal centres narrowed further from first year onwards indicating the differential development phases between the two, that riverine centre was active in the early stages while coastal centre was active in the third and sixth year phase.

The per cent increase by coastal and riverine centres over inland centre was respectively 16.73 and 74.08 in the first year, followed by 32.20 and 203.38 per cent in the third year and 47.80 and 117.76 per cent in the sixth year for root weight. It is apparent that the coastal centre continued to produce more roots over the three growth periods while riverine centre had declined root development comparatively (from 203.38 to 117.76 per cent) at the sixth year.

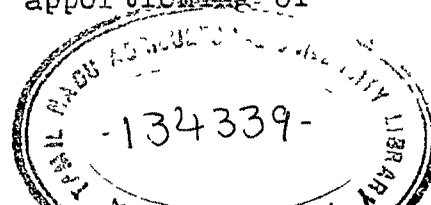
Between coastal and riverine centres, there had been a spurt in growth of roots in riverine centre from 49.09 per cent in the first year to 129.48 per cent in the third year and a decline to 47.35 per cent in the sixth year.

The per cent increase of total biomass by the coastal and riverine centres over inland had scored 15.1 and 85.9 per cent in the first year, that rose to 27.13 and 141.45 per cent in the third year. However, in the sixth year, the increase had risen to 36.12 per cent by coastal centre and slightly decreased by riverine to 120.66 per cent. Concurrently the superiority of the riverine over the coastal centre that increased from 61.48 per cent in the first year to 69.82 per cent in the third year declined to 40.10 per cent in the sixth year.

When the biomass over the three age classes was taken as a whole, it was apparent that the riverine areas exerted an assertive rate of growth in the first to third year after which it slid down, while coastal and inland areas attained a relatively superior growth after the third year and maintained a discrete increase.

5.8. Apportioning biomass

At the juvenile stage, mean apportioning of



biomass at the end of one year ranged from 68.54 per cent for stem in coastal area, followed by 69.11 per cent in riverine and 67.38 per cent in inland centres (Tables 21, 22 and 23).

On the contrary, at the third year the per cent contribution of stem to the total ranged from 28.0 to 51.1 per cent for coastal with a mean of 45.4, 44.2 to 56.2 with a mean of 49.9 for riverine and 41.7 to 60.5 per cent with a mean of 50.2 per cent for inland areas (Tables 25, 26 and 27).

At the sixth year, coastal centre had 47.4 to 59.7 per cent of stem with a mean of 53.3 per cent, riverine 45.1 to 62.4 with a mean of 55.8 and inland samples showed a range of 50.2 to 63.0 with mean of 59.0 (Tables 31, 32 and 33).

The progressive increase of biomass allocation from the third year to sixth year towards stem is in conformity with the observations of Das and Ramakrishnan (1987) who reported that in the above ground biomass in Pinus kesiya, the dry matter allocation was more towards the stem with increasing age from 1 to 22 years.

However, in the case of Allantnus excelsa (Pande et al., 1988) for a comparable/ period, the mean weight

of branches had been in the range of 13.7 to 20.1 while *Casuarina* showed 17.0, 13.9 and 16.8 per cent for coastal, riverine and inland centres at age of three, followed by 10.3 in coastal and 8.7 in riverine and 8.0 in inland series of plantations at age of six. The decrease in allocation over time for branch component is accountable as biomass is turned over to building the stem. The progressive decrease over age had been recorded similarly for *Pinus kesiya* (Das and Ramakrishnan, 1987) and *Casuarina equisetifolia* (Verma et al., 1987 and Chakrabarti 1984).

The needle weight as a per cent to the total was 16.84 for coastal, 16.38 for riverine and 16.46 for inland areas for the first year, followed by 22.40 in coastal, 17.30 in riverine and 18.00 in inland centres for third year. In the sixth year, the percentages continued to be 16.90, 15.40 and 13.20 for the three centres respectively. This sustained percentage at three and six year indicated the replenishment of needle along the length of the crown despite the annual litter-fall accounting for 3725 kg/ha/yr in coastal area for example (Table 43).

The per cent contribution to the root in the first year was 15.22 for coastal, 13.71 for riverine and 15.83 for inland centres. The trend was akin to third year for coastal

centre with 15.4 per cent, followed by riverine at 18.7 and inland with 15.0. At the sixth year, the percentages were 14.1, 15.2 and 14.7 respectively for coastal, riverine and inland centres. The amount of decrease in total weight of roots is anticipated with increasing age but the consistency with which the per cent is maintained offers an explanation that the components of root system is continuously growing with lesser root decay or replaced with high frequency of secondary thickening to show a comparable increase over the years. This aspect could be one of the reasons for the versatility of C. equisetifolia to be successful in more than one centre.

The above ground and total biomass produced by the three vastly different environments are reflected in the total weight that had ranged distinctly for each plantation series (Table 21, 22, 23, 25, 26, 27, 31, 32 and 33) showing differences between them. Despite the quantity of the biomass, where each component like stem, branch, needle and root was evaluated on the basis of percentage to the total, there was an indication that the centres had not influenced each component differently in relation to the contribution to the total weight (biomass).

5.9. Litter-fall

The amount of litter contained in the 1.0 x 1.0 m

spaced plantation was 4.55 t/ha/yr that was apportioned as 3.03, 0.52, 0.05 and 0.95 t for needle, cone, inflorescence and twigs respectively. In the 1.5 x 1.5 m spaced plantation, the litter components were needle 2.61 t, cone 0.44 t, inflorescence 0.07 t and twigs 0.94 t, all totalling to 4.06 t. With regard to the widely spaced plantation at 2.0 x 2.0 m, the total litter of 3.71 t could be apportioned as needle 2.46 t, cones 0.42 t, inflorescence 0.08 and twigs 0.75 t.

A cumulative measurement of all the three differently spaced plantations showed 43.1 per cent of the litter was obtained during the April-June period (I Quarter), followed by 23.2 per cent in the July-September period (II Quarter), 20.3 per cent in the October-December (III Quarter) and 16.4 per cent January-March (IV Quarter) period indicating an uniform pattern in litter-fall during I and II quarters and slightly low proportion in III and IV Quarters. More than sixty per cent of the respective litter component had been recorded in the first two quarters from April to September of which the first quarter contributed a major share.

The periodicity of the fall follows an unimodal pattern unlike the case of Eucalyptus species reported by

Pande and Sharma (1986) wherein the leaf fall was observed to be in two peaks; the first one during October-November with 22.0 per cent and the second with 18.80 per cent of the litter-fall during April-May. In C. equisetifolia, the first quarter (April-June) had a litter-fall comprising 39.7 per cent of needle, 30.2 per cent cones, 36.6 per cent inflorescence and 22.6 per cent twig. This was followed by 24.9 per cent of needle, 30.16 per cent cones, 15.2 per cent inflorescence and 45.9 per cent twigs in the second quarter (July-September). The litter-fall was high during the rainless summer months and approached an unimodal distribution (Table 39). It can be ascribed to the evergreen nature of Casuarina where total deciduousness is not encountered. It followed almost the unimodal pattern of litter-fall of Eucalyptus in Australia, its parent country, where eucalyptus and acacia shed their leaves during the months of December to May with a peak in the months of December to January (Hatch, 1955). The unimodal litter fall was also influenced by the seasonal climate, as witnessed for sal (Shorea robusta) and other mixed species (Pande and Sharma, 1986). This coincided with the drier periods of the year when evapotranspiration and temperature were on the rise.

The litter-fall in the case of widely spaced (2.0 x 2.0 m) plantations at six year age in coastal and riverine areas showed a similar pattern as above, although

the total quantity of litter-fall received was variable between the two plantations. The distribution over time followed the same pattern as seen in the differently spaced plantations.

The quantum of litter-fall encountered in this species equalled to that of Pinus patula plantations of 4 years of age, that had released 3145 kg/ha (Bhartari, 1986) and 3748 kg/ha for a 10 year old similar species (Singh, 1979). George (1982) recorded 3377, 3801 and 6207 kg/ha for 5, 7 and 10 year old eucalyptus plantations respectively with densities from 1133 to 1167 number of trees per ha. Kira (1978) encountered 10.82 t of plant litter in tropical low level rain forests of South East Asia.

The differences between the quantity of litter accumulation in coastal and riverine soil is understandable because of the varied nutrient status in both the soils. Perala and Alban (1982) reported that litter-fall was lower in sandy or loam soils as compared to river alluvium due to differences in nutrient levels.

The proportionality of differences in the per cent component of the litter (needle, cone etc.,) between the two environments for the same age (four years)

is almost negligible except that the riverine plantation showed higher twig fall (20.2 per cent of coastal to 24.7 per cent of riverine plantation). The differences between ages were apparent in that needle component was higher by 5.0 per cent in the riverine plantation. With a standard spacing, the species had reached its silvicultural maturity in six years due to high nutritional level of the soil while the coastal plantation was yet lagging behind. Increased abscission of leaf, twig etc. is triggered by a closed canopy that competes for light. Management wise, this is the rotation age for felling the plantation. If the plantation is to show further exponential growth, it needs to be thinned and canopy opened so that further growth can be accelerated (Smith 1986). On the basis of total litter-fall, the component of needle fall in riverine plantation (62.4 per cent) was slightly higher than the coastal area (57.4 per cent). The coastal area showed increased cone fall (10.3 per cent) as compared to the riverine plantation (7.0) and also the inflorescence. The percentage component for twigs was almost identical for both the plantations (30.6 and 29.3 per cent). In this litter-fall, the large share of needle agreed with other reports mentioning that it formed upto 70 per cent of the local litter for above ground (O' Neil and De Angelis 1981, Meentmeyer et al 1982).

5.10. Soil nutrients

The level of pH in the soil remained almost constant in the case of plantations upto the age of three years. A reduction of pH was seen in the coastal and inland soils at the fourth and sixth year. It has been shown (Table 40) that the coastal plantations released 3725 kg of litter per year per hectare and riverine plantations released 5755 kg/ha at the age of four years. They also released 6023 kg of litter from the coastal plantation in the sixth year and 9811 kg from the riverine plantation at six years of age. This could be ascribed to acidification of litter components and increased N production through root nodules of this species.

The species actively fixed nitrogen with age and growth of the tree. In the process they extrude protons and so contributed to the lowering of soil pH (Binkley 1986). The acidification during nitrogen fixation in soils low in nitrate can be considerable. Alfalfa yielded 10 tonnes per ha dry weight which fixed 270 kg/ha N and contained 120 meq/100 g excess base that would produce acidity equivalent to 600 kg calcium carbonate per ha (Nyatsanga and Pierre 1973). The acidifying effect of Alnus crispa on the upper most horizon of a glacial till reduced pH from 8 to 6 within 20 years (Crocker and Major 1955).

The extractable cation content of infertile soil increased under nitrogen fixing alders in a mixed stand with Douglas-fir. Increased biomass production as evidenced by plantations growth, nitrification coupled with nitrate leaching and mineral weathering had enhanced acidity. The organic matter favoured soil aggregation and aeration, increased cation exchange capacity and ability of the soil to retain nutrients. Harvey et al (1978) reported that pH of mineral soil (0-20 cm) beneath Alnus rubra was significantly lower than pH of the soil under Douglas-fir. The decrease of pH with increasing age of the plantation could be ascribed to increased composition of greater organic matter, acid production and higher nitrification rates. Further, the increasing decomposition of C. equisetifolia needles caused increased peaks of CO_2 production and maximum concentrations of exchangeable Fe and Mn and other cations. These concentrations were also significantly higher as compared to controls and influenced the soil pH and exchangeable sodium percentage and the accumulation of cation (Swarup 1988).

The EC of the soil in the coastal centres was appreciably higher compared to inland and riverine areas. This was due to the transport and deposition of salts from the sea due to wind and ingression of sea water in the past. In the other two centres, the salt content was much less.

Despite the higher salt content, C. equisetifolia was able to perform better because of its resistance to high salinity (Yadav 1983, Ng 1987). The salt concentration in the soil was uniformly distributed at all depths in all the centres. EC did not vary with age among the centres.

The increased deposition of litter on the surface soils over the years in the coastal, inland and riverine plantations added to the source of organic matter. The higher per cent of lignification had also contributed to slow decomposition on the surface soil. Soil organic matter was higher by about 25 per cent under alder stands (Borman and DeBell 1981). Similar increase in organic carbon with the age of the plantation was also reported by Sharma et al (1985) in Alnus nepalensis plantations.

The productivity of organic matter by C. equisetifolia was double that of other legume species like Albizia stipulata (Thiyagalingam and Fahmy 1979). The high organic carbon content in the riverine soil, as compared with the coastal and inland soil, was also due to the transported alluvial soil rich in organic matter. Soil carbon is increased under the influence of nitrogen fixing plants including Alnus rubra (Borman and DeBell 1981, Tarrant and Miller 1963, Binkley 1986). Alnus stipulata

(Binkley 1986), Ceanothus velutinus (Binkley et al., 1982). A significant increase in the rate of carbon and mineral content increases has been noticed beneath A. rubra stands (Cole et al., 1978). There was a progressive increase (0.5 - 1.0) in the organic carbon content with the age of plantation in all the centres, due to the cumulative addition over time as reported for Alnus nepalensis by Sharma et al (1985).

The high calcium in the coastal area is considered due to the marine effect (Yadav 1983). This has also been consistently higher in the surface soil in all the centres. It increased progressively through age series because of accretion of litter and its by products. Casuarina responded to higher calcium in the soil and it had been one of the added advantages for its versatility (Puri 1958, Qureshi et al., 1967).

Calcium has been shown to increase nodulation of several legumes with the earliest stages of infection (Lowther and Lonerogan 1968). Calcium ions affect the initiation of infection of modification of the host cell wall which aided in the attachment of Rhizobium. This explained the beneficial role of high calcium in the coastal soil (Israel and Jackson 1978). The rapid acidification of the growth medium caused

by actinorhizal plants and their ability to reduce soil base content, in particular calcium, are well documented. Despite the increased leaching of minerals from soils due to the presence of acid~~by~~-products of the decomposition of litter, and the high rates of H^+ extrusion from the roots consequent upon nodule activity, the calcium balance in the coastal and alluvial soils are maintained (Israel and Jackson 1978).

Among the three plantation areas, the nitrogen content had been high in the riverine area and an increase of 84 kg (55.26 per cent over control) had been observed. In all plantations, the surface soil recorded higher available N. This could be ascribed to the addition of 52.8 kg of N obtainable through decomposition of litter and further supplemented by nodulation (Table 49). The available N status in the surface soil increased with age of the plantation due partly to the cumulative function of decomposition. The increased nitrogen accretion in the fourth and sixth years might also be due to increased root activity for nitrogen fixation as reported by Lommergues (1963, 1986).

Varying quantities of nitrogen fixation to the extent of 68 kg/ha/yr in Alnus crispa (Crocker and Major 1955) and 86 kg/ha/yr in Cenothus velutinus (Youngberg and Whollum

1976) have been recorded for temperate situations. Similar accretion has been reported to the tune of 63 kg by Dommergues (1963) for the tropical C. equisetifolia. Ovington (1962) was of the opinion that substantially more nitrogen must be fixed than was accumulated with the ecosystem. He opined that high rates of the fixation occurred when forest vegetation had counterparts of root nodule bearing species.

The level of phosphorus had increased in all the plantations over time. Sharma et al (1985) also found that available phosphorus increased with increasing age of the Alnus nepalensis plantation. The P status on the surface soil had been appreciably higher than the subsoil. This was partly to the decomposition of litter and release of phosphorus that added upto 4.73 kg/ha/yr. Organic matter being the main source of soil phosphorus, it had contributed to the higher P status in the surface soil. It decreased down the depth in all the plantations.

The higher P content in the surface soil and its diffusion to the root zone due to high water table in the coastal area (Yadav 1983) and high soil moisture state in the alluvial soil of the riverine area had contributed to higher nodulation in the riverine and coastal plantations as compared to the inland. As phosphorus increased, the phosphatase enzymes activity had resulted in increasing nodulation activity.

Phosphorus is released primarily by direct action of phosphatases at the stage of soil organic matter. It also forms salts with calcium which are most soluble and moderate to abundant only in soil of near neutral pH as in these cases (Binkley 1986).

Further, the fine textured soils of alluvium permit faster diffusion of phosphorus than the coarse textured soils of the coastal sand. This had accounted for higher growth rate and P uptake as reported by Kadeba et al (1975). Similar beneficial influence of soil texture and phosphorus for higher growth rate of plantation crops was reported by Wilde et al (1965) for red pine in Wisconsin. Day Jr. (1982) showed that decay rates were apparently higher in the more flooded sites and produced maximum phosphorus correlated with rate of decay as it happened in the alluvial, riverine soil where flooding is frequently encountered.

The level of potassium is constant for the first four years in all the areas and in all the horizons. This can be attributed to the fact that potassium is a highly mobile mineral which moves down the profile. The continuous weathering of potassium bearing minerals in the lower horizons also accounts for the uniform distribution of potassium in the different horizons. The rate of mineral

weathering of K is calculated at 21 kg/ha/yr (Feller 1981). Further, the marginal increase of potassium is felt in the sixth year that could be ascribed to the release of K by decomposition of the litter-fall. It is present only in free, ionic forms in plants and its release from litter is usually faster than any other nutrient (Binkley 1986).

The data in Table 49 indicated the uptake of minerals per annum, their retention in different locations in the tree and their return to the soil through litter. The amount released to coastal soil was relatively lower than riverine soil presumably to higher levels of biomass accretion in the later. Complementary to other non-nitrogen fixing species, the amount of nutrients retained within the standing biomass is lesser than uptake, as shown for both the coastal and riverine areas. This followed the pattern of Pinus patula (Malhotra et al., 1987). The high amount of calcium released (113.1 kg per ha in coastal and 163.9 kg in riverine soils) though must have been recycled as this is a calcium demanding species (Puri 1958). Qureshi et al (1967) reported that Mg uptake was highest in 5-9 years old plantations and presumably its cycling was also efficient. The nitrogen yield had been substantial with riverine soils reporting two fold increase and was in conformity with high nitrogen levels in tropical dense plantings with nitrogen fixing species (Dommergues 1963, 1986; Kiro 1978). It is also

to be noted that the stem holds sizeable quantity of nitrogen, magnesium, calcium and potassium a feature characteristics of Casuarina (Verma et al., 1987) contrary to broad leaved species. The release of phosphorus that was two fold in riverine areas indicated the high biomass and litter accretion. The increase in nutrient content of standing crop reflected the condition of the growing site and its environment (Ovington 1959).

From a soil that had 85 kg nitrogen (coastal) and 152 kg (riverine), the amount of uptake had been substantial at 171.7 and 327.4 kg. The vast gap between the availability and requirement should have been met from the nitrogen fixing nodules since the quantity of 144.9 kg of nitrogen released through litter-fall is hardly sufficient to meet the ecological balance through intracycling (Binkley 1986).

The production of cones in relation to the total dry weight showed a range from 1.9 to 10.9 kg for the various trees aged six studied in the three ecosystems though limited to ten or nine trees per area for which total dry matter was available. Kondas (1983) reported a yield of 10 kg of dry cones from a single border tree 10 years of age. The present output for the six year old trees conformed to the above.

The average yield of seeds per kg of cone ranged from 21 g for coastal, 22.4 g for riverine and 17 g for inland areas followed the published information. The productivity of cones as sink per tree had varied from 6.61 to 9.17 percent. This generally applied to the results of Harper and Love (1970) as reported for Senecio vulgaris. However, the cone yield at the current plantation areas had reflected an increase in yield, an effect of the habitat also. The productivity was higher in lesser nutrient rich areas like coastal and inland ecosystems, while it was comparatively lower in rich soils of river alluvium, where much of the assimilates had channelled into production of non reproductive biomass unlike the other two areas. On the contrary, the seed yield per kg of cone was comparatively higher in riverine areas, the seed.

It has been mentioned elsewhere that the riverine population was more stable genotypically, but from seed production point of view, its genetic potential for cone production is apparently weak and when the high biomass yielding clones of these populations are moved into seed production stands, a managerial implication is warranted for maximising source sink.

SUMMARY

VI. SUMMARY

In the present study with Casuarina equisetifolia Forst, seed germination and seedling behaviour of seeds obtained from different areas of cultivation, their genotypic stability, biomass accretion and nutrient cycling have been studied.

Seeds of *Casuarina* collected from plantations from three different ecosystems viz., coastal (Marakkanam), riverine (Natham) and inland (Virudhachalam and Coimbatore) showed variation in 100 seed weight, germination per cent, speed of germination and rate of growth of seedlings when raised in a common environment at Coimbatore. Seeds from riverine areas showed maximum seed weight, germination per cent, speed of germination and high rate of seedling growth followed by the seed source from coastal areas. Differences in germination per cent was also highly significant between the different sources. The increase in germination and speed of germination in riverine source indicated that germination responses were strongly associated with seed development and size which got selected favourably under natural conditions.

Grade scores were assigned to seed from the different locations involving nine traits, five traits of the

parents and four traits of the seed and seedling characters. The seeds from riverine source showed a maximum score of thirty six followed by the coastal source recording a score of twenty four only. Both Virudhachalam and Coimbatore locations representing inland ecosystem had a score of 15 only indicating these locations undesirable for seed collection.

The species C. equisetifolia set seeds profusely and germination was fairly high. Small but numerous seeds, absence of dormancy, low seed rate required for unit number of seedlings, high speed of germination, widely spaced plantings unlike that of annuals, reposed multiple advantages in selecting elite trees of proven seed for genetic improvement and effective management. All these endowments combined together offered scope for comparatively rapid genetic improvement in this tree species. Improvement in seedling stock could be thus attained through identification of riverine ecosystem which provided large size seeds and all the attendant advantages conferred with it.

The location of seed collection had a significant influence over the seed quality characters and this could efficiently be combined with seedling selection for better seed stand and performance at initial stages and increased

apportionment of biomass to the trunk. This would be a desired direction for evaluation of the performance of the selections from riverine and coastal ecosystems till the felling stage. As an initial step towards selection of genotypes, seeds collected from select trees from three locations representing coastal, riverine and inland ecosystems were also evaluated for their genetic stability based on growth performance over a time span of 6, 9 and 12 months from planting. It was found that families of riverine areas to be consistent and stable for their performance over coastal and inland families. Five out of ten families from riverine ecosystem and one out of ten from coastal ecosystem, showed comparatively high performance while none from the inland ecosystem was recognisable. The responsiveness of tree seedlings over three growth phases for three plant traits, of height, diameter at collar and number of branches had indicated some of the families to be distinct for their enhanced performance especially from riverine (Family 11, 12, 13, 14 and 16) and coastal (Family 6) sources.

The estimates of various genotypic parameters brought out the absence of large differences between genotypic and phenotypic variances.

The casuarina population from riverine ecosystem was little influenced by growth duration, as expressed by the

low GCV for several traits. The fall of GCV estimates from the first growth phase to the third phase indicated the impact of environment on growth. The difference between phenotypic and genotypic coefficient of variation was low and this would enable to exercise effective selection especially for height and diameter of stem at collar. High heritability estimates were obtained in all the three growth stages indicating that genetic factors were largely responsible than site factors in determining growth rate. Plant height, diameter at collar and number of branches in the coastal and inland sources showed high values of heritability and genetic advance thereby according scope for genetic improvement by selection.

The genotypic evaluation and genetic divergence with respect to important juvenile traits brought out that stability was very high to high for parameters such as height and diameter and a few of the families had higher mean performance and high stability as well.

An overall consideration from genetic estimation and mean performance indicated adoption of the multistage selection could be recommended. There is scope for prescribing selection norms and indices at seedling stage also

to ensure selection of genetically superior plants. This, coupled with seed selection and selection for high total biomass would result in high productivity for fuel/energy wood. Breeding approaches also have been indicated based on the studies with casuarina.

Divergence studies brought out existence of 8 clusters, of which cluster V had high mean values for height and diameter represented by family 6 of coastal and family 16 of riverine ecosystems.

The open pollinated families that have been evaluated through their progeny performance indicated the possibility of using some of the elite families for developing clones or progenies or populations of superior performance. Its amenability to vegetative propagation will be a handy tool for clonal assemblage.

It was also found that in the above ground partitioning of biomass the stem shared maximum allocation followed by needle and branches. A progressive increase in allocation towards stem was observed from the third year to six year in conformity with the previous studies in casuarina. There was a progressive decrease in allocation of

branches over time stages in contributing to the biomass. However, in an overall average, less than ten per cent of biomass was allocated to the branches in the sixth year growth. The contribution of branchlets that exist as needles was substantial, accounting from 13.2 to 16.9 per cent of the total biomass at the sixth year in all the three areas. Roots contributed from 14.1 to 15.2 per cent to the total biomass at six years of growth. At three years, roots contributed 13.3 to 18.7 per cent.

Height was one of the dominant and determinant characters in biomass estimation. Casuarina seedlings from riverine and coastal ecosystems exerted a superior performance over inland and showed initial advantage of height in the first year and sustained this to the felling. In contrast, riverine samples showed a lag phase in growth between third and sixth year while the inland selections showed slow growth at initial period followed by an active phase. A similar trend was noticed for diameter at collar and weight of branches measured through first, third and sixth year. Needles (branchlets) expressed an active production phase through third to sixth year period in the case of riverine selections. The production of needle indicated an increasing trend in growth while a decline in the per cent growth was evident in the traits like height, diameter, stem weight and root weight,

in the third to sixth year period. Root weight followed the pattern of needle.

The total biomass increase in coastal and riverine ecosystems was 15.1 and 85.9 per cent over inland selections in the first year followed by 27.13 and 141.45 per cent in the third year 56.12 and 120.66 per cent in the sixth year. Riverine ecosystems exerted assertive rate of growth in the first to third year after which it slowed down while coastal and inland areas maintained a relatively faster growth after the third year.

In respect of production in terms of wood, among the three ecosystems, riverine plantation showed two fold production of an average of 79.9 kg per tree against inland plantation, where the weight was only 36.8 kg at the sixth year. As far as inter-relationship of different contributory components were concerned, high significant correlation existed between total weight and plant height, diameter at collar, stem weight, needle weight and root weight in respect of samples studied from riverine, inland and coastal ecosystems. Among these components, stem weight showed positive significant association with bark, branch, needle and root weight.

The litter-fall was quantified for coastal plantations of four years with three different espacements like 1.0 x 1.0, 1.5 x 1.5 and 2.0 x 2.0 m. Closely spaced plantation (1.0 x 1.0 m) generated 4.5 t litter per ha/year while plantation of 1.5 x 1.5 m and 2.0 x 2.0 spacing released 4.0 t and 3.7 t respectively indicating closer the spacing, heavier the litter-fall. Among the litter components, needle contributed from 64.30 to 66.59 per cent among the three espacements followed by twigs ranging from 20.22 to 20.89 per cent and the rest by reproductive parts. Among the reproductive plants, the cones contributed 10.83 to 11.43 per cent to the total litter-fall.

The periodicity of litter-fall followed an unimodal pattern with most of the litter-fall during the first quarter (April-June) accounting for 32.2 to 48.0 per cent in the three differently spaced plantations. The unimode pattern was also noticed in six year old riverine and coastal plantations too. Dry summer months coupled with increased evapotranspiration have been ascribed as cause for higher litter-fall during the summer months from April to June. Riverine plantation showed relatively more litter-fall than coastal plantation because of higher biomass in the former. On a per cent basis, coastal plantations had 19.0 per cent of the biomass while riverine had 24.0 per cent diverted for litter-fall.

The quantum of litter-fall in mature riverine and coastal plantations was proportionate to the total biomass despite the vastly different accretion levels.

Casuarina equisetifolia is a soil enricher and known for improving soil nutrients overtime. The level of pH in the case of the three plantations was not influenced by the crop upto an age of three years but a reduction was seen in the coastal and inland soils at the fourth and sixth year. The electrical conductivity (EC) in the coastal area was slightly higher than inland and riverine areas due mostly to transport and deposit of salts from the sea. A progressive increase in the organic carbon content was observed with age of the plantation in all the centres due largely to the addition caused by decomposition of litter. The progressive increase in calcium on the surface soils was due to calcium released by dry needle that contained upto 2.0 per cent of calcium of dry weight.

The nitrogen increment in the riverine areas had been high upto 84 kg/ha/year as compared to the control. In all plantations, surface soil recorded higher available N, ascribed to release of nitrogen through decomposing litter and release from nodules. The phosphorus status on the surface soil increased with age, partly due to

decomposition of litter and organic matter releasing the major share. It was particularly high in riverine situation where diffusion through high moisture movement and fine textured soil was feasible. Potassium was marginally increased due to release by decomposing litter and weathering of K bearing minerals in the soil.

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* Originals not seen

PLATE 1. CASUARINA PLANTATION - NEAR PUDUKKOTTAI

PLATE 2. CASUARINA - SINGLE TREE

PLATE-1



PLATE-2



PLATE 3. CASUARINA - CROWN FORM

PLATE 4. CASUARINA - BRANCHLETS (NEEDLES)

PLATE-3



PLATE-4

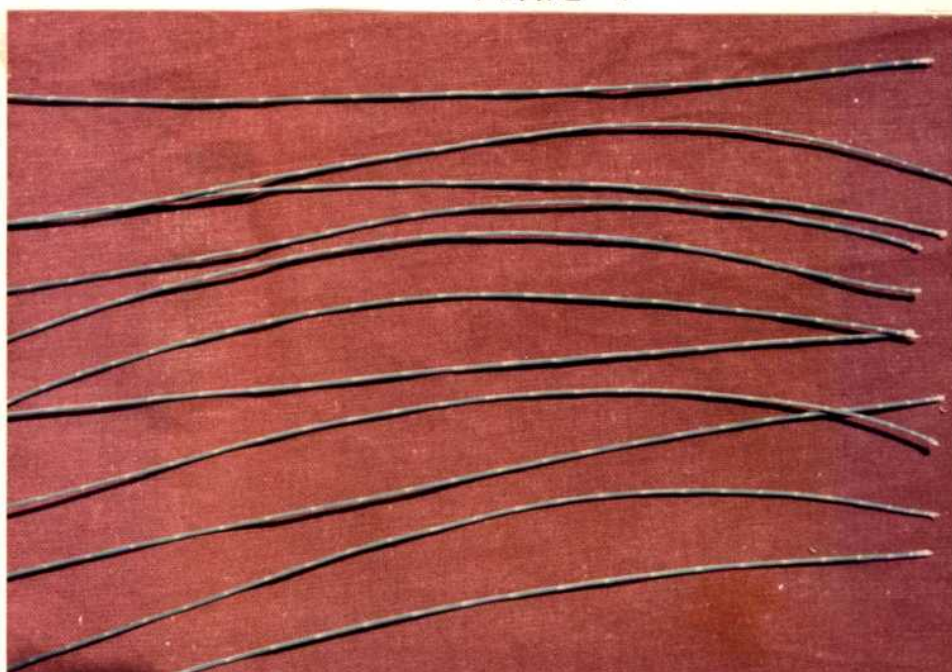


PLATE 5. CASUARINA - MALE INFLORESCENCE

PLATE 6. CASUARINA - MONOECIOUS TYPE

PLATE- 5

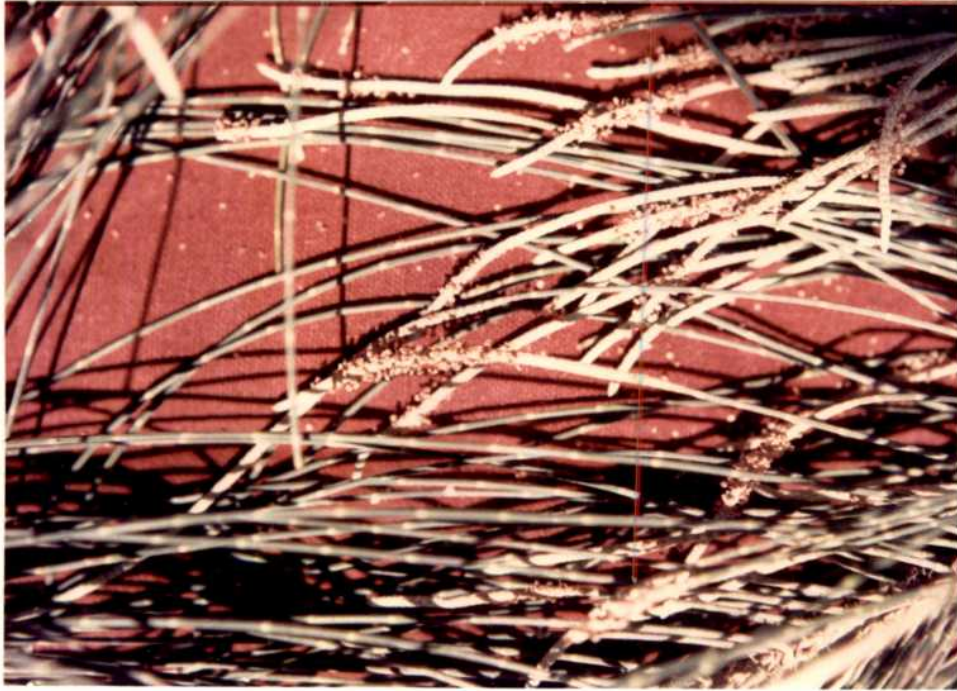


PLATE-6



PLATE 7. CASUARINA - TWIG WITH CONES

PLATE 8. CASUARINA - VARIATION IN CONE SIZE

PLATE- 7

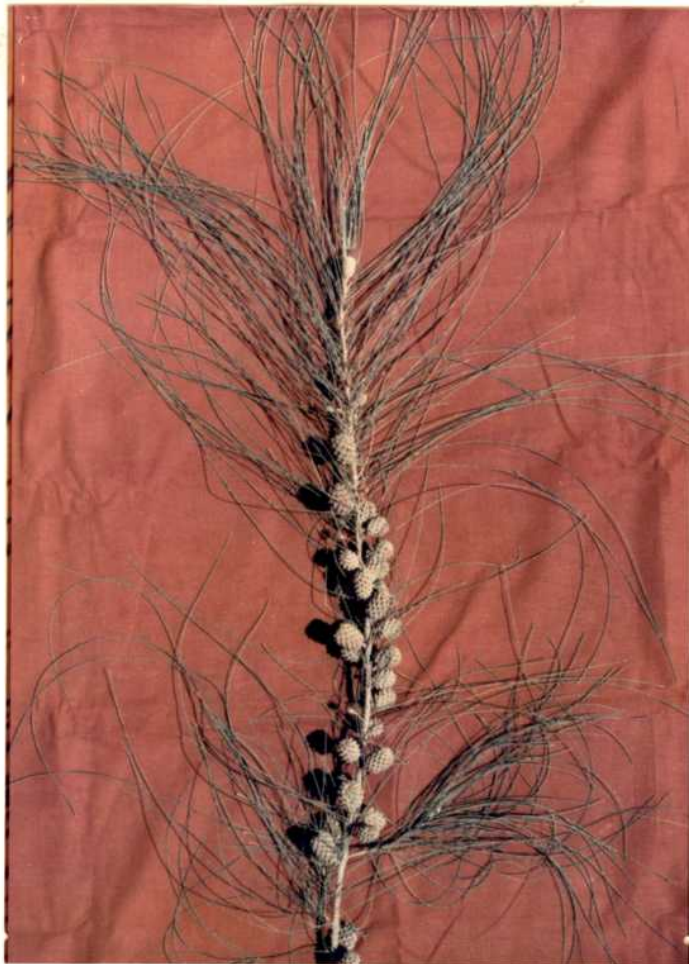


PLATE-8

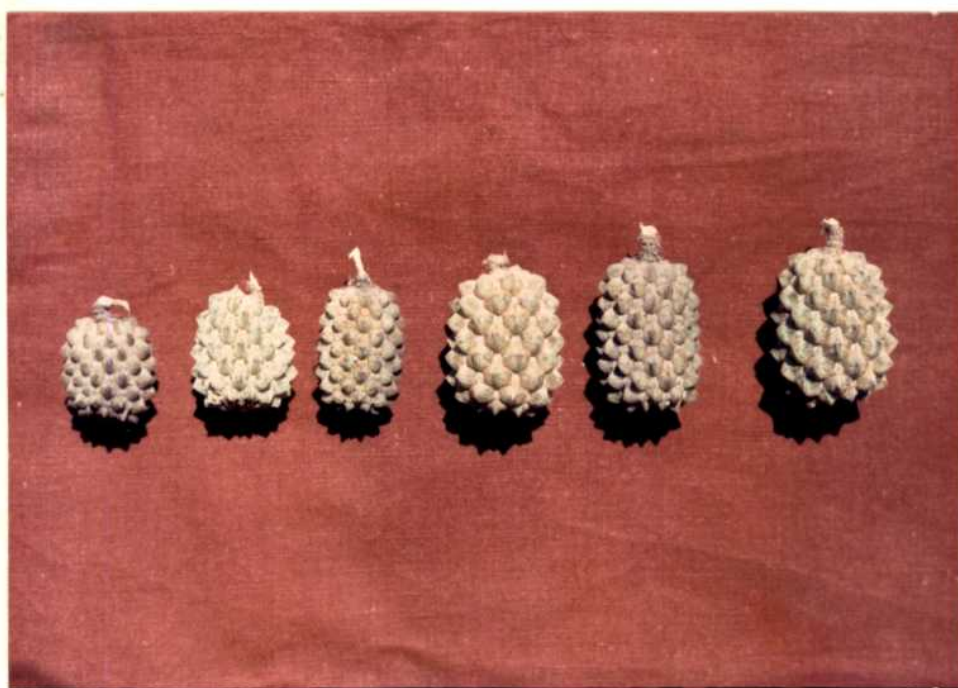


PLATE 9. CASUARINA - SEEDS

PLATE 10. CASUARINA - SEEDLINGS - FOUR MONTHS OLD

PLATE - 9



PLATE - 10



APPENDIX-I

Family range and mean for height growth at six months

Source	Family No.	Mean cm	Maxi- mum cm	Mini- mum cm	CV %
Coastal	1	55.9	88.0	38.0	25.1
	2	51.7	80.0	28.0	27.7
	3	47.9	72.0	25.0	31.0
	4	57.5	70.0	38.0	17.0
	5	45.8	65.0	27.0	19.3
	6	85.1	11.2	64.0	46.2
	7	58.7	72.0	39.0	17.9
	8	57.6	82.0	23.0	32.2
	9	51.9	67.0	29.0	21.9
	10	64.6	95.0	24.0	35.1
Riverine	11	70.4	113.0	53.0	21.5
	12	84.5	119.0	59.0	20.7
	13	77.4	120.0	32.0	21.5
	14	77.3	100.0	52.0	20.8
	15	80.9	105.0	64.0	19.0
	16	88.9	124.0	57.0	21.2
	17	71.5	128.0	53.0	25.0
	18	73.6	102.0	48.0	20.2
	19	80.3	105.0	57.0	16.6
	20	63.0	95.0	37.0	23.7
Inland	21	45.2	67.0	24.0	28.6
	22	53.0	72.0	27.0	24.1
	23	46.0	67.0	28.0	26.4
	24	64.9	93.0	39.0	23.7
	25	57.3	87.0	25.0	30.6
	26	57.9	75.0	39.0	18.7
	27	70.5	95.0	45.0	20.4
	28	52.4	65.0	39.0	14.0
	29	60.8	81.0	39.0	18.9
	30	41.0	57.0	22.0	27.6

APPENDIX-II

Family range and mean for height at nine months

Source	Family No.	Mean cm	Maxi- mum cm	Mini- mum cm	CV %
Coastal	1	78.7	120	57	20.7
	2	73.2	112	42	25.7
	3	67.1	96	42	26.2
	4	80.2	95	49	17.2
	5	65.9	94	43	16.6
	6	116.4	137	94	10.9
	7	83.2	101	65	16.4
	8	77.2	114	80	29.0
	9	85.0	105	40	22.3
	10	90.0	130	40	32.3
Riverine	11	96.3	137	78	15.6
	12	107.6	140	82	17.4
	13	103.3	154	75	21.1
	14	100.5	127	73	17.1
	15	98.7	129	80	15.6
	16	109.8	139	78	15.0
	17	91.6	131	71	22.4
	18	96.6	125	68	18.5
	19	94.5	121	79	13.5
	20	85.0	121	62	19.7
Inland	21	58.2	88	36	22.4
	22	72.5	95	40	21.7
	23	66.6	89	42	24.6
	24	87.2	120	52	23.8
	25	77.2	109	50	25.7
	26	80.6	102	55	16.0
	27	98.0	129	66	16.5
	28	74.9	89	57	14.3
	29	82.0	101	65	13.7
	30	56.2	72	40	22.0

APPENDIX-III

Family range and mean for height at twelve months

Source	Family No.	Mean cm	Maxi- mum cm	Mini- mum cm	CV %
Coastal	1	102.6	148.0	80.0	18.26
	2	93.8	136.0	56.0	24.10
	3	91.4	118.0	61.0	22.59
	4	105.0	131.0	69.0	16.51
	5	87.8	125.0	72.0	16.38
	6	138.5	161.0	114.0	11.62
	7	117.7	137.0	50.5	19.71
	8	101.6	127.0	56.0	20.95
	9	104.1	148.0	64.0	19.47
	10	108.8	154.0	50.0	31.50
Riverine	11	125.9	170.0	106.0	13.00
	12	137.4	171.0	105.0	16.16
	13	142.5	194.5	109.0	16.56
	14	136.2	166.0	105.5	16.53
	15	132.1	169.0	106.5	13.78
	16	149.1	188.0	114.0	12.79
	17	126.7	154.0	104.0	16.84
	18	127.6	158.5	93.0	16.07
	19	123.5	149.0	99.0	13.49
	20	115.7	158.0	92.0	17.86
Inland	21	87.3	117.5	52.0	21.59
	22	89.8	116.0	70.0	18.31
	23	88.4	121.0	60.0	22.43
	24	104.4	135.0	70.0	18.08
	25	100.9	135.0	55.5	21.41
	26	96.3	122.0	70.0	13.86
	27	124.1	158.0	86.0	16.00
	28	98.5	117.0	73.0	13.18
	29	106.8	131.0	85.0	12.43
	30	84.2	106.0	57.0	20.14

APPENDIX-IV

Family range and mean for diameter at six months

Source	Family No.	Mean cm	Maxi- mum cm	Mini- mum cm	CV %
Coastal	1	0.53	0.70	0.30	23.8
	2	0.44	0.75	0.30	26.9
	3	0.41	0.60	0.20	30.6
	4	0.45	0.60	0.30	18.2
	5	0.37	0.45	0.28	16.3
	6	0.74	0.95	0.55	13.6
	7	0.53	0.75	0.40	17.6
	8	0.53	0.75	0.30	28.7
	9	0.50	0.65	0.30	18.6
	10	0.51	0.85	0.25	31.3
Riverine	11	0.61	0.75	0.42	31.4
	12	0.71	1.30	0.55	27.6
	13	0.65	1.20	0.50	24.2
	14	0.68	0.90	0.45	17.3
	15	0.76	0.90	0.60	14.2
	16	0.76	1.00	0.40	24.2
	17	0.61	1.00	0.40	28.4
	18	0.62	0.90	0.40	23.0
	19	0.54	0.80	0.40	19.9
	20	0.54	1.00	0.30	37.1
Inland	21	0.54	0.55	0.25	22.7
	22	0.68	0.60	0.30	17.7
	23	0.50	0.70	0.35	22.8
	24	0.59	0.85	0.45	16.9
	25	0.38	0.70	0.30	25.7
	26	0.41	0.70	0.40	17.8
	27	0.45	0.85	0.50	16.7
	28	0.46	0.55	0.35	12.2
	29	0.61	0.75	0.40	18.4
	30	0.54	0.50	0.25	20.5

APPENDIX-V

Family range and mean for diameter at nine months

Source	Family No.	Mean cm	Maxi- mum cm	Mini- mum cm	CV %
Coastal	1	0.62	0.75	0.50	13.3
	2	0.56	0.80	0.40	21.7
	3	0.55	0.80	0.40	20.7
	4	0.61	0.75	0.45	13.8
	5	0.50	0.55	0.40	8.9
	6	0.98	1.10	0.70	11.3
	7	0.69	0.85	0.50	16.0
	8	0.68	0.95	0.45	22.6
	9	0.62	0.70	0.50	12.2
	10	0.69	0.95	0.40	22.1
Riverine	11	0.79	1.35	0.55	24.6
	12	0.94	1.40	0.70	20.5
	13	0.90	1.30	0.65	19.0
	14	0.82	1.00	0.55	15.9
	15	0.92	1.10	0.70	13.6
	16	0.92	1.15	0.50	19.3
	17	0.76	1.15	0.50	22.5
	18	0.77	1.10	0.50	19.9
	19	0.78	1.10	0.55	18.4
	20	0.67	1.10	0.55	27.2
Inland	21	0.54	0.68	0.40	15.1
	22	0.54	0.78	0.42	15.8
	23	0.63	0.93	0.50	18.8
	24	0.73	0.95	0.50	14.3
	25	0.66	0.85	0.40	20.0
	26	0.68	0.90	0.50	15.8
	27	0.83	1.00	0.65	14.2
	28	0.63	0.70	0.50	9.9
	29	0.73	0.90	0.50	17.1
	30	0.52	0.70	0.40	15.6

APPENDIX-VI

Family range and mean for diameter at twelve months

Source	Family No.	Mean cm	Maxi- mum cm	Mini- mum cm	CV %
Coastal	1	0.9	1.3	0.7	22.58
	2	0.8	1.2	0.5	21.92
	3	0.8	1.2	0.5	24.84
	4	1.0	1.4	0.6	18.32
	5	1.0	1.1	0.8	9.00
	6	1.0	1.2	1.0	7.92
	7	0.9	1.2	0.7	15.31
	8	0.9	1.2	0.5	19.80
	9	0.8	1.3	0.6	20.30
	10	1.0	1.5	0.6	30.30
Riverine	11	1.1	1.4	1.0	9.40
	12	1.2	1.5	0.9	14.40
	13	1.2	1.5	0.9	16.16
	14	1.2	1.6	1.0	17.68
	15	1.3	1.6	1.0	12.96
	16	1.0	1.5	1.0	11.24
	17	1.1	1.4	0.9	13.75
	18	1.1	1.5	0.9	7.60
	19	1.1	1.5	0.8	17.29
	20	1.0	1.4	0.8	18.54
Inland	21	0.7	1.0	0.4	24.17
	22	0.8	1.2	0.6	19.98
	23	0.8	1.0	0.5	22.94
	24	0.9	1.3	0.6	21.25
	25	0.9	1.2	0.5	25.24
	26	0.9	1.1	0.6	16.96
	27	1.1	1.3	0.7	15.28
	28	0.9	1.0	0.7	14.58
	29	1.0	1.2	0.8	13.66
	30	0.7	1.0	0.5	25.71

APPENDIX-VII

Family range and mean for branches at six months

Source	Family No.	Mean cm	Maxi- mum cm	Mini- mum cm	CV %
Coastal	1	51.4	71	32	20.5
	2	37.4	62	22	30.7
	3	34.4	43	17	33.4
	4	52.4	78	25	28.2
	5	34.6	52	21	24.9
	6	61.6	82	41	17.3
	7	42.6	66	27	23.8
	8	45.3	80	15	40.9
	9	43.6	65	21	26.3
	10	47.4	72	21	32.5
Riverine	11	75.4	112	52	17.8
	12	76.2	125	55	22.7
	13	78.4	120	58	19.9
	14	62.4	92	42	27.4
	15	77.7	111	51	28.9
	16	69.4	90	43	19.1
	17	67.6	90	36	22.0
	18	78.0	101	52	78.0
	19	67.4	97	39	21.4
	20	46.5	72	30	32.7
Inland	21	34.7	55	21	29.1
	22	42.6	53	19	22.4
	23	42.6	66	25	23.1
	24	61.6	74	45	17.6
	25	48.4	71	20	29.2
	26	50.2	72	35	21.6
	27	74.0	95	53	15.7
	28	49.3	72	29	22.8
	29	60.9	82	42	17.9
	30	32.4	44	15	26.1

APPENDIX-VIII

Family range and mean for number of branches at nine months

Source	Family No.	Mean cm	Maxi- mum cm	Mini- mum cm	CV %
Coastal	1	75.5	104	49	19.6
	2	66.9	99	41	27.1
	3	65.6	110	42	34.3
	4	81.0	120	42	23.8
	5	65.0	82	42	19.3
	6	94.6	119	69	16.4
	7	69.4	96	54	17.9
	8	71.8	112	24	32.8
	9	71.0	104	40	22.0
	10	77.4	116	40	31.5
Riverine	11	109.8	145	84	14.8
	12	106.7	157	85	16.3
	13	108.2	147	85	13.1
	14	97.9	129	72	15.5
	15	105.2	159	82	20.8
	16	94.9	124	65	16.1
	17	97.2	132	60	21.8
	18	107.8	132	80	14.1
	19	91.9	121	56	17.3
	20	74.2	99	40	24.4
Inland	21	58.8	86	35	22.4
	22	68.5	92	30	23.8
	23	76.4	96	46	16.4
	24	103.4	102	57	16.3
	25	82.0	115	47	23.2
	26	82.2	106	52	19.6
	27	106.5	126	84	-
	28	81.7	104	52	15.5
	29	92.6	120	80	12.2
	30	58.8	82	31	27.5

APPENDIX-IX

Family range and mean for number of branches at twelve months

Source	Family No.	Mean cm	Maxi- mum cm	Mini- mum cm	CV %
Coastal	1	96.4	127	67	15.25
	2	90.1	126	52	23.76
	3	87.9	142	53	27.40
	4	103.4	145	53	21.38
	5	87.7	108	60	15.83
	6	118.8	152	90	15.17
	7	91.8	129	64	18.90
	8	92.9	125	50	26.50
	9	91.7	122	48	21.06
	10	93.5	125	54	25.30
Riverine	11	140.0	175	106	15.68
	12	132.0	179	112	14.22
	13	132.8	177	103	12.55
	14	128.6	162	97	12.34
	15	143.5	197	115	17.27
	16	130.3	165	100	12.00
	17	121.8	172	82	20.60
	18	134.4	159	95	12.74
	19	119.6	142	86	13.87
	20	96.9	130	60	22.85
Inland	21	86.8	120	64	20.73
	22	93.2	123	42	24.83
	23	98.2	121	60	16.06
	24	126.7	152	68	16.38
	25	110.6	146	67	19.99
	26	113.1	142	75	17.96
	27	121.4	157	95	12.74
	28	106.6	143	73	14.91
	29	104.5	132	84	13.66
	30	84.7	114	52	20.83

