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BIOMASS PRODUCTION IN *CASUARINA EQUISETIFOLIA* PLANTATIONS IN THE COASTAL PLAINS OF KERALA

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ABSTRACT

The present study was conducted in an age series of *Casuarina equisetifolia* plantations grown in the coastal areas of central zone of Kerala, comprising three districts viz., Trichur, Malapuram and Ernakulam. Eighteen plantations of different ages ranging from 2 to 9 years were selected for the study. Studies on growth parameters of trees at different ages indicated that diameter and height almost doubled from 2 to 5 years but from 5 to 9 years, the increase was marginal. Biomass production of sample trees revealed that the above ground biomass (agb) of the biggest tree was seven times as much as that of the smallest tree. Percentage distribution of various components to agb was in the order: bole > needle > branch > bark > twig. Percentage contribution of bole biomass increased with increase in ages. However, the percentage of needle decreased with age. Percentage contribution of bark, branch and twig did not show a definite trend with increase in ages. The percentage of bgb to agb showed an increasing trend with increase in ages. Above ground biomass production was ranged from 42.3 t/ha (2 year) to 366.6 t/ha (9 years). Above ground productivity also exhibited considerable variations as it is showed an increasing trend with increasing ages. It was ranged from 21.2 t/ha/yr (density 5133 trees/ha) at age 2 years to 40.8 t/ha/yr (density 5267 trees/ha). Biomass production as well as productivity showed a leveling off at the age of 5 years.

Key words : Height - Diameter - Biomass production - Casuarina - Productivity.

INTRODUCTION

Casuarina equisetifolia is indigenous on sandy shores and dunes along the coast of Chittagong, Tenasserim and the Andamans, particularly in the Little Andaman, also in Malay Archipelago, the Malay Peninsula, the Pacific islands, North Australia and Queensland. It is cultivated in greater part of India, not only along the coast, but also inland as an ornamental or avenue tree and some times in plantations. It thrives best in close proximity to the sea on loose sand, growing sometimes within a few yards to high tide level. It is a nitrogen-fixing tree of considerable social, economic and environmental importance in many tropical areas of world. It is the most widely planted *Casuarina* species and more than 1.5 million hectares of plantations are already being established in China, India and Vietnam. In these countries *Casuarina* planting provides a major source of household income for rural communities and help to sustain the coastal land form through its ability to stabilize moving sands (Pinyopursresk 1996).

Productivity, the rate at which biomass is synthesized is an important ecological parameter. Ecosystem productivity is an index which integrates the cumulative effects of the many processes and interaction. Net production by an individual plant is the amount of organic matter that it synthesizes and accumulates in tissue per unit time (Whittaker & Marks 1975). The productivity of natural forest in India is only 0.69 m^3/ha/yr. Keeping this in view, many fast growing species were introduced and suitable management practices were adopted to enhance the productivity. To evaluate the impact of such operations, data on biomass production have to be generated. Therefore, productivity studies of fast growing species have been accorded high priority in the present day research.

MATERIALS AND METHODS

Study site, Climate and soil : This study was conducted in an age series of Casuarina equisetifolia forest plantations grown in the coastal areas of central zone of Kerala, comprising three districts viz., Trichur, Malapuram and Ernakulam which lie between 90 55' to 11° 32' N and 75° 50' to 76° 53' E. Eighteen plantations of different ages ranging from 2 to 9 years were studied and these plantations were raised and maintained by the Kerala Forest Department. The area receives an average annual rainfall of 3229 mm, of which about 73 per cent is received from Southwest monsoon, about 25 per cent from the Northeast monsoon and remaining from summer showers. Average annual temperature of the area is 28.5° C Maximum temperature (39.2° C) is recorded in the month of March and minimum (19.9°C) in the month of December. March is considered as the hottest month and December, the coldest month. Average relative humidity of the area is 73.5 per cent.

Dry matter production of sample trees: Field studies were confined to sample plots in the plantations employing stratified average tree technique (Madgwick 1971). Five to ten sample plots of size 10 m x 10 m were laid out and diameter at breast height (dbh) of each tree in the sample plot was recorded. The trees were grouped into five diameter classes by frequency distribution method and an average tree of each diameter class was selected for sampling. Thus five average trees were felled from outside the sample plot. A total of 90 trees were harvested for estimating above ground biomass.

The sample trees were cut at the ground level with the help of a bow saw and total height was recorded. All branches were removed from the main stem and branches were grouped into twigs (below 5-cm girth (ob)) and branches (above 5 cm (ob) & below 20 cm (ob)). Needles (Phylloclades) were also separated from the branches. The main bole was limited to 5-cm girth (ob). Green weight of main stem, branches, twigs and needles was recorded separately. Hundred-gram representative sample from each component was taken and packed in paper bags and transported to laboratory for dry weight estimation and chemical analysis. Dry weight of wood and bark of each billet was estimated using mean wood: bark ratio of two successive discs. Biomass of each sample plot was calculated after multiplying weight of each sample tree by the number of trees in their respective diameter class and adding the above values to get total biomass. From the above plot level biomass, biomass on per hectare basis was computed. Out of 90 trees sampled, complete root system of 69 trees was dug out.

The roots were excavated by the skeleton method (dry excavation), i.e. digging along the course followed by the roots in the soil mass. Hundred-gram fresh sample was made proportionately from different zones of the root and packed in paper bags and transported to laboratory for oven dry weight estimation and chemical analysis (Puri *et al* 1994).

RESULTS AND DISCUSSION

Growth parameters : Mean values at different ages indicated significant variations in diameter and height (Table 1). At 2 years, diameter and height was 4.4 cm to 7.0, respectively and at 5 years of age, it significantly increased to 9.6 and 12.8 respectively. Gurumurthi and Rawat (1989) reported that in *Casuarina equisetifolia*, diameter and height growth at 2 years were 1.6 cm and 3.3 m respectively, whereas at 5 years, the corresponding figures were 6.9 cm and 10.7 m, respectively. Table 1 also indicated that the age markedly influenced the growth rate. Diameter and height growth were more rapid during early years than during later years. Lugo *et al* (1990) also observed that the increment in diameter of *C.equisetifolia* at younger ages was comparatively more than that at older ages.

Above ground biomass (agb): Though the plantations were of even aged, there existed great variations in the agb and biomass of components within a particular plantation of any age. The difference in agb of lowest and highest diameter classes within a 5-year-old plantation was as high as eleven times. This is consistent with the findings of Verma *et al* (1987) in *C.equisetifolia*. They reported that such difference in agb was 5 times at the age of 5 years. The greater variations observed in the present study were mainly due to higher diameter variations (4.4 cm to 12.6 cm). Similar difference in agb and biomass of components was also observed in plantations of other ages. Such variations in agb in different ages were also reported by Williams *et al* (2005) in eucalyptus woodlands. Above ground biomass (agb) and biomass of different components generally increased with increase in diameter and height (Table 1). At age 5 years, diameter and height were 9.6 cm and 12.8 m, respectively and agb was 39.2 kg whereas at the age of 9 years, diameter and height were 12.6 cm and 16.6 m, respectively and the corresponding agb was 79.0 kg. Similar observation on increasing trend in biomass production with increasing diameter and height was also reported by several workers in *C.equisetifolia* (Srivastava 1994; Kushalapa 1987; Sugur 1989; Kumar *et al* 1998).

Table 1 Growth parameters and biomass of components of average trees at different ages (kg/tree)

Age (yrs)	Dbh (cm)	Height (m)	Bole (ub)	Bark	Branch	Twig	Needle	Agb	Bgb	Grand total
2	4.35^{d}	6.95^{c}	3.80^{e}	0.57^{b}	1.01^{c}	0.10^{c}	1.19	6.68^{d}	1.25^{c}	7.93^{d}
3	6.49^{c}	9.47^{bc}	9.76^{de}	1.05^{b}	2.19^{bc}	0.57^{bc}	3.10	16.67^{cd}	3.11^{c}	19.78^{cd}
5	9.57^{b}	12.82^{ab}	26.22^{cd}	1.92^{b}	6.03^{abc}	1.39^{a}	3.59	39.15^{bc}	6.34^{bc}	45.48^{bc}
7	11.06^{ab}	15.68^{a}	40.54^{bc}	3.88^{a}	7.72^{ab}	1.29^{ab}	4.58	58.01^{ab}	12.31^{ab}	70.32^{ab}
8	11.76^{a}	16.27^{a}	58.34^{ab}	4.49^{a}	11.00^{a}	1.35^{a}	3.56	78.73^{a}	15.79^{a}	94.53^{a}
9	12.60^{a}	16.63^{a}	60.42^{a}	4.83^{a}	7.84^{ab}	1.34^{ab}	4.53	78.95^{a}	17.78^{a}	96.73^{a}
F-table	32.909^{**}	8.084^{**}	13.910^{**}	8.695^{**}	3.522^{*}	4.604^{*}	2.233^{ns}	13.053^{**}	8.681^{**}	13.939^{**}

**Ssignificant at 0.01 levels; * Significant at 0.05 levels; ns non significant at 0.05 levels. Means with same letter as superscript are homogeneous

Among the different components, bole contributed the maximum to agb (48 to 73%) (Fig.1). It is generally observed that in trees, the shoot system develops at faster rate in order to produce canopy as rapidly as possible to exploit high light energy. Therefore biomass production of bole will be maximum when compared to other components. Studies conducted by Kushalapa (1987) in *C.equisetifolia* revealed similar findings. Studies in *C.equisetifolia* by Lugo *et al* (1990) revealed that the per cent contribution of stem wood was the highest (76%) compared to other components. Relatively higher per cent of bole was also reported in *C.equisetifolia* by several workers (Verma et al 1987; Jambulingham 1989; Srivastava 1994). In the present study the per cent distribution was in the decreasing order: bole > needle > branch > bark > twig. Similar findings were also reported in *C.equisetifolia* by Gurumurthy and Rawat (1989).

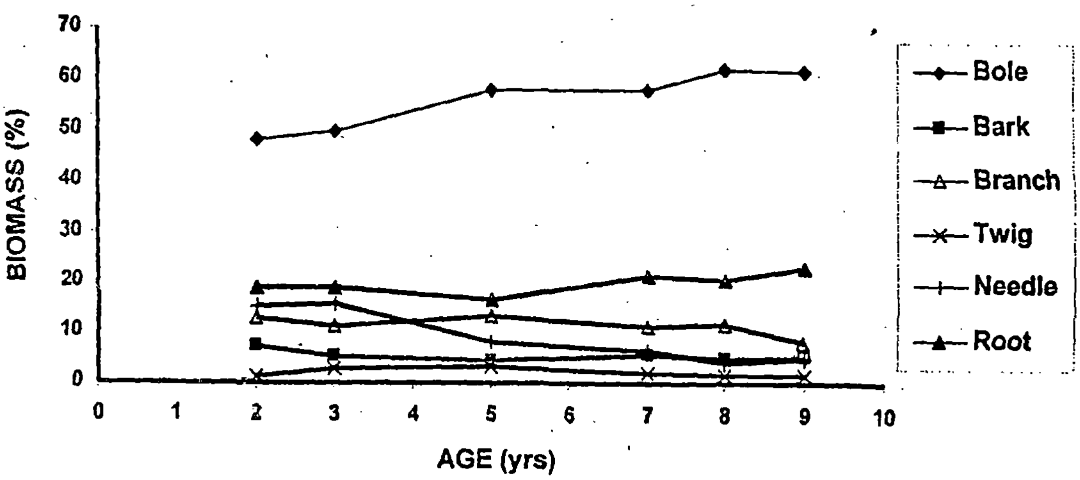

Fig. 1 Percentage contribution of components of average trees of *C.equisetifolia*

Below ground biomass: *Casuarina equisetifolia* is endowed with a well-developed taproot system, which extends to a depth of 1 to 1.5 m in a sandy soil. The lateral roots become congested and interwoven to form a net like mass under close spacing. Considerable variations in bgb were as discernable within a plantation of any age. At the age of 5 years, bgb of largest tree was 7 to 10 times as much as that of smallest tree. Generally bgb increased with increase in diameter and height (Table 1). At age of 2 years, diameter and height of sample trees, increased from 4.4 cm to 7.0, respectively to 12.6 cm and 16.6 m at 9 years of age and correspondingly bgb also increased from 1.3 to 17.8 kg. Srivastava (1994) reported in *C.equisetifolia* that at 6 years, diameter and height of trees increased from 3.8 cm to 9.1 cm and from 6.1 to 9.4 m, respectively and bgb also showed corresponding increase from 2.8 to 8.0 kg.

Dry matter production per unit area : As noticed in individual tree basis, dry matter production on unit area basis increases with increase in age. At the age of 2 years, agb was 42.3 t/ha and it increased more than 4 times (175.1 t/ha) at the age of 5 years. Study conducted by Lugo *et al* (1990) revealed that in *C. equisetifolia*, agb at the end of 1st year of growth was 13.6 t/ha and it increased to 199.7 t/ha at age 5 years. The positive relationship between age and biomass production is again evident. In plant populations, accumulation of biomass with age takes place continuously until the rotation ages due to annual increment in diameter and height. This is true in case of population with sigmoid growth pattern (Srivastava 1995). The biomass production, a function of age has also reported in *C. equisetifolia* by Das *et al* (1998). As in the case of agb, other components barring needle and twig also showed conspicuous increase with advancing age. Increase in agb was maximum during early years compared to old ages. At the age of 2 years, agb was 42.3 t/ha and at 3 years it doubled to 89.7 t/ha, whereas agb which was 320.2 t/ha at 8 years and at the age of 9 years increased marginally to 366.8 t/ha. Similar findings were reported in *Dalbergia sisoo* by Sharma et al (1988) at age 24 years. This rapid early growth may be due to the fact that biomass production at younger ages is under conditions of high nutrient supply (Dovon et al 1998). In general agb was more influenced by diameter and height than by stand density. That agb is a function more of growth parameters than of stand density as observed by Verma *et al* (1987) in *C.equisetifolia* and Antonio *et al* (2007) in *Eucalyptus globulus*.

Table 2 Biomass production (t/ha) of *C.equisetifolia* plantations at different ages

Age (yrs)	Density (Trees/ha)	Av.DBH (cm)	Av.Ht (m)	Bole (ub)	Bark	Branch	Needle	Twig	AGB	Root	Grand Total
2	5133	4.5	7.5^{a}	22.32^{a}	3.28^{a}	7.92^{a}	8.20^{a}	0.59^{a}	42.31^{a}	9.09^{a}	51.4^{a}
3	5167	6.1	9.46^{b}	49.17^{a}	5.15^{a}	15.15^{ab}	16.39^{b}	3.89^{ab}	89.74^{a}	20.47^{b}	110.2^{a}
5	4300	8.9	13.04^{c}	116.59^{b}	9.14^{b}	28.48^{bc}	14.89^{b}	6.03^{ab}	175.13^{b}	35.64^{c}	210.8^{b}
7	4367	9.6	13.2^{c}	165.81^{b}	17.00^{c}	40.61^{c}	18.74^{b}	4.56^{b}	246.72^{c}	51.40^{cd}	298.1^{c}
8	5233	9.7	12.8^{c}	231.04^{c}	18.61^{c}	49.95^{c}	14.99^{b}	5.62^{ab}	320.21^{d}	72.24^{d}	392.5^{d}
9	5267	9.8	12.9^{c}	269.41^{c}	18.76^{c}	50.35^{c}	22.06^{b}	6.24^{b}	366.82^{d}	74.43^{d}	441.3^{d}

Mean values with same superscripts are homogenous and others are significant
* significant at 1% level

Productivity: Productivity studies at different ages indicated marked variations in the plantations of same age. These variations may mainly be attributed to locality factors. Biotic pressure as well as seasonal inundation also might have affected productivity. In the present study, productivity was 21.2, 29.9, 35.0, 35.2, 40.0 and 40.8 t/ha/yr, respectively at 2, 3,5,7, 8 and 9 years (Table 3). There was not much difference in the productivity between 8 and 9 years. Jayaraman *et al* (1992) reported that *C. equisetifolia* growing in the West Coast of Kerala produced 35 t/ha/yr at the age of 5.5 years. In this present study also, at the age 5 of years, productivity was 35 t/ha/yr. This is due to the fact that the studies relate to localities of similar agroclimatic conditions. Lugo *et al* (1990) also observed that in *C. equisetifolia*, productivity at age 5 years was 40 t/ha/yr. Productivity on unit area basis showed a leveling off beyond 5 years. Similarly bgb, at 5 years was 7.1 t/ha/yr but increased meagerly to 8.3 t/ha/yr at the 9th year. This suggests that a period of 5 years is the ideal rotation age for this species.

Table 3 Productivity of *C.equisetifolia* plantations at different ages (t/ha/yr)

Age (yrs)	Density (Trees/ ha)	Av.DBH (cm)	Av.Ht (m)	Bole (under bark)*	Bark NS	Branch NS	Twig *	Needle *	AGB *	Root *	Grand Total *
2	5133	4.5	7.5	11.12^{a}	1.6	4.0	0.3^{a}	4.1^{a}	21.2^{a}	4.5	25.7^{a}
3	5167	6.1	9.5	16.4^{a}	1.7	5.1	1.3^{b}	5.5^{a}	29.9^{ab}	6.8	36.7^{ab}
5	4300	8.9	13.0	23.3^{b}	1.8	5.7	1.2^{b}	3.0^{ab}	35.0^{b}	7.1	42.2^{b}
7	4367	9.6	13.2	23.7^{bc}	2.4	5.8	0.7^{c}	2.7^{ab}	35.2^{b}	7.3	42.6^{b}
8	5233	9.7	12.8	28.9^{c}	2.3	6.2	0.7^{c}	1.9b	40.0^{b}	9.0	49.1^{b}
9	5267	9.8	12.9	29.9^{c}	2.1	5.6	0.7^{c}	2.5^{b}	40.8^{b}	8.3	49.0^{b}

Mean values with same superscripts are homogenous and others are significant
* Significant at 1% level, NS - Non significant at 5% level

Investigation on biomass production of *Casuarinas equisetifolia* plantations in the coastal plains of Kerala revealed considerable variations in their growth parameters within the same ages as well as between the age groups. The variations are significant between the ages but not the case with plantations of similar ages. Within an age group, the variations in diameters between the smallest and biggest trees were three to four fold. Similarly diameter and height showed an increasing trend with increase in age. Diameter and height almost doubled from 2 to 5 years but from 5 to 9 years, the increase was not significant.

Biomass production of sample trees revealed significant variations in their above ground biomass (agb) as well as in their biomass components within a plantation. At the age of 5 years, the agb increased 5 times to that of age at 2 years, whereas at 9 years, it increased only 2 times compared to that of 5 years. There was a significant increase in agb from age 2 to 5 years, but this was not true from age 5 to 9 years. This indicated a levelling off in biomass beyond 5 years. Percentage distribution of various components to agb was in the order: bole > needle > branch > bark > twig. On unit area basis at age 2 years, agb was recorded as 42.3 t/ha and it increased to 366.6 t/ha at age 9 years. This showed that when age increased from 2 years to 9 years, the agb increased 9 times to that of 2 years.

Productivity exhibited considerable variation among plantations of similar ages. At age of 2 years agb productivity was 21.2 t/ha/yr (density 5133 trees/ha) and at the age of 9 years, it reached to 40.8 t/ha/yr (density 5267 trees/ha) and as in the case of biomass production, there was a leveling off at older ages. This revealed that 5 year is being the optimal rotation age for the species.

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