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Productivity studies in selected commercial tree species of tropics

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ABSTRACT

Detailed investigations were conducted in Kera1a Agricultural University, Vellanikkara to evaluate the growth performance, biomass production, physical properties of wood and leaf nutrients of commercial multipurpose tree species grown in the arboretum during the period from 1992 to 2007. A total of 12 species were included in the study with an objective of screening the promising species for their further multiplication for large scale distribution to farmers for farm/agro forestry and general afforestation programme. The results of the study revealed that among the species studied, species like *Terminalia tomentosa*, *Terminalia bellerica*, *Acacia auriculiformis* and *Acacia mangium* were found fast growing in terms of most of the vegetative growth parameters studied. The total biomass production was found to be maximum for *Terminalia tomentosa* followed by *Adenanthera pavonina* while the lowest total biomass was produced by *Swietenia macrophylla* in terms of both fresh and dry weight. Trunk accounted for maximum biomass production followed by branches. *Acacia mangium* and *Acacia auriculiformis* produced more heartwood compared to other species. *Terminalia bellerica*, *Artocarpus hirsutus* and *Acacia auriculiformis* were having high calorific values and hence could be used for fuel wood purpose also. Specific gravity was found to be maximum for *Swietenia macrophylla* and minimum for *Terminalia bellerica*. The N and P content were found to be maximum in *Adenanthera pavonina* while potassium in *Tectona grandis*. The present series of investigations clearly indicate that there is wide scope for selecting tree species based on their growth behaviour, wood properties and tissue nutrient content before recommending for commercial cultivation under social/agroforestry programme.

Key words : Growth,Biomass, Specific gravity, Calorific value, Heartwood, Sapwood

INTRODUCTION

Raising plantations in degraded areas and other bare lands play an important role in promoting sustainable development in the tropics by reducing the pressure on natural ecosystems for fibre, timber, fuel wood, fodder and other needs. Planting of quick growing multipurpose tree species which can meet the various needs of the community, is of great importance in social/farm forestry system. Trees will also help in arresting the deterioration of the environment and improving the quality of life of people. To achieve the above objectives, a thorough knowledge of growth habit of various tree species is inevitable. Biomass produced by tree species is also important for carbon sequestration and these trees should be useful for small timber purpose also. So the wood properties and biomass production should be given importance in the choice of species. In addition to fodder values, leaf biomass of tree species are rich sources of nutrients which are essential for plant growth. Incorporation of leaf litters will improve the nutrient status of the soil without any deleterious effects on physical or chemical properties. Hence, selection of tree species with leaf biomass rich in nutrients is another need of the day. The present study was taken up to enable the researchers to screen the species for various purposes.

MATERIALS AND METHODS

The present investigations were carried out at the instructional farm, College of Forestry, Kerala Agricultural University, Vellanikkara, Thrissur, Kerala, during the period 1992 to 2007. The experimental materials consist of 12 trees each of 12 important tree species planted in the instructional farm at a spacing of 4 x 4 m. Uniform seedlings were planted during 1991-92 and are being maintained. The species included in the study were: *Acacia auriculiformis* (Acacia), *Acacia mangium* (Mangium), *Adenanthera pavonina* (Manchadi), *Ailanthus triphysa* (Matti), *Artocarpus hirsutus* (Anjali), *Bridelia retusa* (Kaini), *Grevillea robusta* (Silver oak), *Swietenia macrophylla* (Mahogany), *Tectona grandis*. (Teak), *Terminalia bellerica* (Thanni), *Terminalia tomentosa* (Karimaruthu) and *Xylia xylocarpa* (Irul).

Height, commercial bole height, girth and number of branches were recoded at yearly intervals. For biomass estimation, the trees were felled and then partitioned into stem wood, branch wood, twigs and foliage. Fresh weights of all the above ground components were recorded tree wise using appropriate spring scales. Moisture percentage of each portions of the felled trees was found out separately and dry weight was estimated. Physical properties like heartwood percentage, sapwood percentage, heartwood: sapwood ratio, bark percentage, calorific value and sp. gravity were determined. The samples of leaves of each of the tree species were dried, powdered and analysed for the major nutrient elements *viz.*, N, P and K using standard procedures.

RESULTS AND DISCUSSION

Evaluation of tree species for growth behaviour:

From the observations recorded, it is apparent that among the ten tree species studied, species like *Terminalia bellerica, T. tomentosa, Acacia auriculiformis, Bredelia retusa* and *A. mangium* were found fast growing in terms of height and girth. *Grevellia robusta, Xylia xylocarpa, Artocarpus hirsutus etc.* showed lowest increment in height and girth. *Artocarpus hirsutus* and *Grevellia robusta,* however, produced maximum number of branches. Commercial bole height of *Tectona grandis* showed maximum increment followed by *Acacia auriculiformis* whereas *Grevellia robusta* recorded minimum increment with respect to commercial bole height. The observations recorded in the present study revealed that the height and girth of *Acacia mangium* was 0.9 m and 7.3 cm, respectively at the age of one year. Lahiri (1984) reported that *Acacia mangium* recorded a height and girth of 2.0 m and 4.0 cm, respectively within one year when planted on the lateritic tract.

In the present study, *Grevellia robusta* was found to be poor in terms of height and girth. This indicates the better suitability of *Grevellia robusta* to subtropical and temperate conditions compared to tropical conditions. The observations recorded in the present study showed that the girth and height of *Acacia auriculiformis* at the end of third year were 35.4 cm and 7.4 m, respectively. Similar studies were conducted by Pandey *et al.* (1987) on *Acacia auriculiformis* plantation in Bihar where at the end of the third year, it recorded a girth of 34 cm and a height of 3.7 m only. This indicates better suitability of *Acacia auriculiformis* to tropical high rainfall area compared to dry subtropical areas.

The observations recorded in the present study clearly reveal that both *Acacia auriculiformis* and *A. mangium* performed well in terms of height and girth. Present study also reveals that *Tectona grandis* was slow growing with regard to girth and height during the first three years. Similarly, Gera *et al.* (1996) conducted a field screening trial of 17 multipurpose tree species grown in acidic soil in the Barha experimental area, Jabalpur and reported the slow growing nature of teak particularly during the initial years. Tiwari *et al.* (1999) analyzed the growth behavior of 39 species of multipurpose trees grown in the arboretum in Madhya Pradesh on sandy loam soil and reported similar growth nature in respect of teak and terminalias.

In the present study, it is seen that the growth rates of most of the species were steady for first five years of juvenile stage. Similarly, Kumar *et al.* (2002) conducted a study on the growth rate convergence in teak trees from three sites in Karnataka and reported that growth rates of similar aged trees were relatively constant even beyond their juvenile stage. The species like *Bredelia retusa* recorded comparatively good volume increment of 0.497 cu.m at. the end of 10 year growth. Growth rate of trees are highly affected either positively or negatively by soil pH, moisture, organic carbon and other nutrient content of soil. The study clearly revealed that the growth rate clearly dependent not only on one site parameter but on the inter relationship of all other related characters.

Evaluation of tree species for biomass production:

From the present study conducted to estimate biomass production, it is evident that the maximum biomass was produced by *Terminalia tomentosa* in terms of fresh and dry weight followed by *Adenanthera pavonina,Acacia auriculiformis, Bridelia retusa, Terminalia bellerica* and *Acacia mangium* (Table 1). The high biomass yield of Acacias can be attributed to its wider adaptability and nitrogen fixing ability (Chundawat and Gautam, 1993), lower transpirational loss of water (Kallarackal and Soman, 1992) and the consequent lower probability of being subjected to an episode of water stress. This is of special significance in view of the monomodal rainfall distribution characteristic of the experimental site. Similar high growth rate and volume production of Acacia stands were reported by Mathew *et al.* (1992). George (1993) also reported a significantly higher value for biomass production for *Acacia, Casuarina, Leucaena* and *Ailanthus* under the similar ecoclimatic conditions of the present study. Jisha (2006) also reported the production of better biomass for *Terminalia tomentosa* compared to other species grown in Vellanikkara conditions.

Artocarpus hirsutus produced 126 kg/plant of fresh biomass in the present study which is very less compared to many other tree species. Gopikumar (2000) has also made similar observations where *Artocarpus hirsutus* was reported to produce lesser biomass compared to *Albizia falcataria*. Jisha (2006) reported total above ground biomass of 319.9 kg/plant for *Terminalia tomentosa*. All these reports are in agreement with the observations made in the present study.

It is also evident from the present study that in all the species, trunk contributed maximum proportion of tree biomass ranging from 59 per cent in *Artocarpus hirsutus* to 82 per cent in *Acacia auriculiformis*. The contribution of branches ranged from 4.0 per cent in *Terminalia bellerica* to 21 per cent in *Swietenia macrophylla* and *Terminalia tomentosa*. Percentage contribution of twigs

Table 1 : Biomass production (kg) of the tree species

Tree species	Trunk			Branch			Twigs			Leaves			Total		
	Fresh weight	Dry weight	Moisture %	Fresh weight	Dry weight	Moisture %	Fresh weight	Dry weight	Moisture %	Fresh weight	Dry weight	Moisture %	Fresh weight	Dry weight	Moisture %
Acacia auriculiformis	233.0	125.8	46.3	19.5	11.4	41.3	16.5	8.1	50.6	23.5	9.6	59.1	292.5	155.0	47.6
Acacia mangium	150.4	82.7	45.1	21.0	12.8	38.7	12.0	7.3	38.7	16.5	5.1	69.0	199.9	108.0	47.9
Adenanthera pavonia	217.2	140.3	40.5	43.0	25.4	41.1	3.9	2.3	39.2	25.0	9.9	50.1	289.1	178.0	48.9
Ailanthus triphysa	119.0	50.0	58.6	25.0	12.2	55.0	19.5	6.5	66.6	41.0	11.2	57.9	204.5	79.9	59.4
Artocarpus hirsutus	71.3	34.5	53.6	17.1	9.1	53.6	7.5	3.5	53.0	30.1	11.0	63.0	126.0	58.1	55.8
Bridelia retusa	186.7	98.2	45.3	45.8	25.6	41.8	31.7	15.2	49.2	8.5	2.16	70.9	272.7	141.4	51.8
Grevellia robusta	125.0	58.9	53.1	8.0	6.8	19.7	20.5	8.7	57.5	40.3	16.0	60.0	194.3	90.4	47.5
Swietenia macrophylla	52.0	29.1	44.8	19.0	10.1	46.4	8.5	4.5	46.4	15.0	4.1	72.4	94.5	47.9	52.5
Tectona grandis	113.8	45.5	60.1	4.5	5.8	59.7	7.5	3.0	59.5	8.5	2.8	66.3	144.3	57.2	61.4
Terminalia bellerica	166.9	80.1	52.6	9.5	4.1	56.1	18.5	8.1	56.2	15.5	3.4	77.9	210.4	95.8	60.7
Terminalia tomentosa	321.9	211.8	34.3	112.6	68.5	37.7	44.0	27.4	37.7	45.0	12.2	71.6	522.4	319.9	45.3
Xylia xylocarpa	113.5	60.2	47.5	19.5	10.3	46.7	19.5	8.0	58.9	30.0	10.3	65.5	182.5	88.9	54.6
F	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**
C.D. (P=0.05)	2.78	2.46	2.44	2.59	2.51	2.38	2.67	2.62	2.81	2.67	2.51	2.78	2.33	2.62	2.90
S.E.±	1.33	1.32	1.16	1.23	1.21	1.13	1.36	1.21	1.34	1.28	1.31	1.29	1.26	1.28	1.12

ranged from 5.1 per cent in *Acacia auriculiformis* and *Tectona grandis* to 10 per cent in *Grevellia robusta*. The range of leaf percentage contribution was from 4 per cent in *Terminalia bellerica* and *T. tomentosa* to 19 per cent in *Artocarpus hirsutus*. Generally the moisture content ranged from 41.4 per cent in *Adenanthera pavonina* to 61.4 per cent in *Tectona grandis.*

In the present study, generally leaves are showing much higher moisture percentage followed by twigs. Trunk showed minimum moisture percentage in all the tree species and was lowest in *Terminalia tomentosa* (34.3%) and *Swietenia macrophylla* (44.8%). In the case of branches, the maximum moisture percentage was observed for *Tectona grandis* (59.7%) and *Terminalia bellerica* (56.1%). Moisture percentage of tree as a whole showed less diversity ranging from 45.3 per cent in *Terminalia tomentosa* to 61.4 per cent in *Tectona grandis*. Most of the trees were recording a moisture nearing 50 per cent. Moisture in the tissues adversely affects the calorific value (Skrinska *et al*., 1999). Water in green tissues exists primarily in the form of free water filling the wood capillaries and water of constitution of the various cell wall components.

Evaluation of tree species for wood properties:

The heartwood percentage of the discs collected from basal portions of tree species was more compared to the discs collected from middle portions and the heartwood from discs from middle portions was more compared to the discs collected from top portions (Table 2). This clearly indicates that heartwood is more accumulated in basal old part compared to younger top part. Being old, more of the wood is converted to heartwood as also reported by Makela (2002). Hence, for using tree species for timber purpose, the wood from the basal portions would be superior as more of heartwood would make the wood harder and more resistant to insect and pest attacks. Sapwood does not show any such regular trends. In many tree species, bark percentage is higher in the top portions of the wood compared to other portions. This may be for giving better protection to sapwood and growing tissues towards the top portion of the tree.

The basal portion of the trunk of *Terminalia bellerica* recorded highest calorific value (7091.79 cal.g^{-1}) followed by *Artocarpus hirsutus* (5187.69 cal.g^{-1}) and *Acacia auriculiformis* (5081.58 cal.g^{-1}). *Bridelia reusa* recorded the least calorific value of 3643.78 cal.g^{-1} followed by *Swietenia macrophylla* and *Adenanthera pavonina* (4057.70 cal.g^{-1}) and *Acacia mangium* (4161.92 cal.g^{-1}). In the middle portion of trunk, *Terminalia bellerica* recorded the highest calorific value

Table 2 : Physical properties of the wood of tree species

Tree species	Base				Middle				Top			
	Heart wood %	Sapwood %	Heartwood: Sapwood	Bark %	Heartwood %	Sapwood %	Heartwood: Sapwood	Bark %	Heartwood %	Sapwood %	Heartwood: Sapwood	Bark %
Acacia auriculiformis	65.04	19.20	3.30	15.75	63.91	24.51	2.60	11.56	56.75	22.70	2.50	20.54
Acacia mangium	72.61	21.42	3.30	5.95	66.35	26.85	2.47	6.79	64.07	28.19	2.27	7.73
Adenanthera pavonia	45.20	47.80	0.94	6.80	30.70	62.30	0.49	6.90	14.50	78.50	0.18	6.80
Ailanthus triphysa	27.15	59.79	0.45	13.04	9.02	82.85	0.11	7.53	11.19	79.10	0.14	9.70
Artocarpus hirsutus	12.18	74.12	0.16	13.70	16.49	6.64	0.24	17.01	15.30	62.31	0.24	22.31
Bridelia retusa	40.51	49.27	0.82	10.22	38.83	50.00	0.78	11.17	37.13	53.31	0.70	9.56
Grevellia robusta	51.02	38.87	1.31	10.10	45.94	37.25	1.23	16.79	28.13	52.31	0.53	19.48
Swietenia macrophylla	48.94	23.79	2.05	24.04	32.96	26.40	1.24	22.40	32.20	45.76	0.70	22.01
Tectona grandis	41.94	42.58	0.98	15.48	44.00	35.20	1.25	20.30	35.60	38.17	0.93	26.23
Terminalia bellerica	46.34	47.77	0.97	5.88	42.85	44.28	0.96	12.85	41.93	37.90	1.10	20.16
Terminalia tomentosa	41.93	34.13	1.22	23.98	26.23	52.56	0.50	21.76	14.86	53.09	0.27	19.50
Xylia xylocarpa	20.12	57.79	0.34	22.07	15.88	67.28	0.23	16.82	11.47	68.57	0.16	37.90
F	**	**	**	**	**	**	**	**	**	**	**	**
C.D. (P=0.05)	2.49	2.50	0.26	2.92	2.53	2.67	0.23	2.89	2.36	2.73	0.21	2.73
S.E.±	1.15	1.25	0.14	1.39	1.27	1.28	0.15	1.44	1.18	1.34	0..11	1.34

(5341.23 cal.g^{-1}) followed by *Acacia auriculiformis* (4775.95 cal.g^{-1}) and *Swietenia macrophylla* (4670.38 cal.g^{-1}) while *Bridelia retusa* recorded the least (3541.73 cal.g^{-1}) immediately followed by *Ailanthus triphysa* (3905.82 cal.g^{-1}). With regard to the top portions of trunk of all the ten tree specics, *Acacia auriculiformis* recorded highest calorific value (5085.01 cal.g^{-1}) followed by *Artocarpus hirsutus* (4621.98 cal.g^{-1}).

Shanavas (2003) has reported the calorific values of 45 important fuel wood tree species grown in Kerala. Based on results, trees were classified into high calorific value trees(>4500 cal^{-1}g), medium calorific value trees (3750-4500 cal^{-1}g) and low calorific value trees(<3750 cal^{-1}g). He has reported high calorific values for bottom portion of trees. In the present study also, generally bottom portion of most of the trees had high calorific value. This may be due to the fact that tissues had low moisture content in these portions of the tree. However, this needs further investigations. Based on the mean calorific values, *Artocarpus hirsutus*, *Acacia mangium*, *Grevellia robusta*, *Swietenia macrophylla* and *Terminalia bellerica* could be classified under high calorific value class.

The specific gravity of wood of various tree species ranged from 0.30 in *Terminalia bellerica* to 0.82 in *Swietenia macrophylla* (Table 3). The species *viz*., *Acacia auriculiformis*, *A.mangium*, *Adenanthera pavonina*, *Artocarpus hirsutus*, *Grevellia robusta*, *Tectona grandis*, *Terminalia tomemtosa* and *Xylia xylocarpa* recorded a specific gravity of 0.62, 0.45, 0.52, 0.45, 0.56, 0.47, 0.62 and 0.54, respectively. In general, the specific gravity of the wood of most of the tree species was lower compared to the specific gravity reported for these species by Sahri *et al*. (1998) This may be due to the fact that in the present study, the trees from where samples were taken were not too old and mature.

Tissue nutrient concentration:

Tissue nitrogen content was significantly highest in *Adenanthera pavonina* 2.34% followed by *Ailanthus triphysa* (1.915%), *Acacia mangium* (1.834%) and *Xylia xylocarpa* (1.638%) (Table 4). On the other hand, *Terminalia tomentosa* recorded minimum (0.981%) nitrogen concentration in the leaf samples. The phosphorus content was also found to be maximum in *Adenanthera pavonina* (0.08%) followed by *Ailanthus triphysa* (0.046%) and *Tectona grandis* (0.045%). However, the difference between these two species was not statistically significant. These two species were followed by *Acacia auriculiformis* (0.041). The lowest concentration of phosphorus was found in the leaves of *Xylia xylocarpa*

Table 3 : Calorific value and specific gravity of wood of tree species

Tree species	Calorific value (cal./g)				Specific gravity
	Base	Middle	Top	Mean	
Acacia auriculiformis	5081.58	4775.95	5085.01	4980.847	0.62
Acacia mangium	4161.92	4109.16	4006.46	4092.513	0.45
Adenanthera pavonia	4057.45	4367.60	4572.57	4332.54	0.52
Ailanthus triphysa	4362.45	3905.82	4213.53	4160.600	0.33
Artocarpus hirsutus	5187.69	4517.59	4621.98	4775.753	0.45
Bridelia retusa	3643.78	3541.73	4209.03	3798.18	0.76
Grevellia robusta	4883.05	4110.08	4412.62	4468.583	0.56
Swietenia macrophylla	4057.70	4670.38	4105.86	4277.980	0.82
Tectona grandis	4413.48	4366.01	4367.91	4382.468	0.47
Terminalia bellerica	7091.79	5341.23	4178.21	5537.077	0.30
Terminalia tomentosa	4165.80	4360.10	4365.15	4297.017	0.62
Xylia xylocarpa	4517.90	4005.12	4520.12	4347.713	0.54
F	**	**	**	-	*
C.D. (P=0.02)	7.50	6.89	17.06	-	0.06
S.E. ±	3.62	3.28	8.17	-	0.03

* and ** indicates significance of values at P=0.05 and 0.01, respectively

Table 4 : Leaf nutrient concentration of tree species

Tree species	Nitrogen (%)	Phosphorus (%)	Potassium (%)
Acacia auriculiformis	1.629	0.041	0.680
Acacia mangium	1.834	0.030	0.800
Adenanthera pavonia	2.340	0.080	0.450
Ailanthus triphysa	1.915	0.046	0.479
Artocarpus hirsutus	1.311	0.016	0.401
Bridelia retusa	2.010	0.020	0.290
Grevellia robusta	1.308	0.025	0.668
Swietenia macrophylla	1.230	0.018	0.465
Tectona grandis	1.071	0.045	0.846
Terminalia bellerica	1.581	0.018	0.419
Terminalia tomentosa	0.981	0.025	0.477
Xylia xylocarpa	1.638	0.014	0.320
F	**	*	**
C.D. (P=0.05)	0.062	0.022	0.221
S.E. ±	0.032	0.011	0.111

* and ** indicates significance of values at P=0.05 and 0.01, respectively

(0.014%) followed by *Artocarpus hirsutus* (0.016%). The potassium content ranged from 0.290 per cent in *Bridelia retusa* to 0.846 per cent in *Tectona grandis*. With regard to higher potassium content, tree species *Tectona grandis*, *Acacia mangium* and *Grevellia robusta* were at par while with regard to lower potassium content, species like *Bridelia aretusa*, *Artocarpus hirsutus*, *Terminalia bellerica* and *Terminalia tomentosa* were uniform. High content of nutrients particularly N, P, K and S in leaf tissues were also reported by Jamaludheen (1994) and Hegde and Gopikumar (1996).

It could be well established that the leaf biomass of most of the tree species contain considerable amount of nutrients, particularly nitrogen, phosphorus and potassium. These leaves can be used as a good manure as a source of nutrients. When the leaf biomass are incorporated to soil, it is exposed to various physical and biological factors resulting the decomposition and this upon mineralization serve as a potential source for most of the macro and micro nutrients to the plants.

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