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Growth and productivity of *Tectona grandis* Linn. f. in plantations and farmlands in coastal zone of Karnataka (India)

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Abstract: The present study was conducted to understand the growth performance and productivity potential of *Tectona grandis* grown in plantation as well as in the farmlands at coastal zone of Karnataka. The growth of teak tree grown in farmland was significantly higher than tree grown in pure plantation. For instance, the overall height (11.95 m), diameter (23.69 cm), clear bole height (6.20 m), tree volume (0.61 m^3) and timber volume (0.33 m^3) was higher in farmland than trees grown in pure plantation (11.60 m, 20.33 cm, 4.90 m, 0.42 m^3 and 0.18 m^3, respectively). However, crown parameters did not show significant difference among trees grown in pure plantations and farmlands. There was a strong influence of age on growth of teak trees grown in both farmland and pure plantation. For instance, tree height (14.72 m) and diameter (30.52 cm) of higher age class (A_4: 21-25 years) was maximum as compared lower age class (A_1: 5-10 years) with values of 8.29 m and 17.14 cm, respectively. Similar trend was also recorded for volume, clear bole height, crown height, crown length and crown diameter in teak. It was concluded that teak grown in farmland may produce higher growth and volume as compared to pure plantation.

Keywords: Farmland, Pure plantation, Silvicultural management, Tree growth

INTRODUCTION

Teak (*Tectona grandis* Linn. f.) is an important world tropical timber species (Family: Lamiaceae), growing naturally in India, Burma, Thailand, Indonesia and Philippines. Teak is one of the most valuable and widely planted species of south India. It has a long history as plantation species due to its valuable timber which is considered as king of timber species. The earliest record of commercial teak plantation, which is known, dates back to 1844, when the British established a plantation in Malabar. The total area under teak in India is about 104 m ha. In Karnataka, teak forests cover an area of 77, 900 ha with an annual production of 7,080 m^3. The growth of teak is influenced by several biotic and abiotic factors. According to India State of Forest Report, the growing stock of India's forests is estimated to be 6047.16 million m^3 (ISFR, 2013). Significantly, out of this volume, 1550 million m^3 or 26% is found outside the actual forest area and mainly managed by smallholder farmers. Of the total growing stock, 4.6% consists of teak, which is the most common species in forest plantations in the country. The total area of teak plantations is reported as 1.7 million ha (Gilbert, 2012).

It is clearly recognized in India that farmers and communities are in key position for fulfilling the national goal of 33% forest cover stated in the National Forest Policy, 1988. There is already a rapid rise in tree cover in agroforestry systems in India, and this gives new opportunities for growing teak by smallholder farmers (GOI, 2009). The systematic management of teak forests started in colonial British India and has continued to the present day all over the tropical world by commonly applying agroforestry practices in plantation establishment (the taungya system and similar approaches elsewhere). However, a distinct disadvantage in this system was the exclusion of farmers from the benefits brought about by trees (Evans and Turbull, 2004).

Long rotations are commonly seen as a problem in growing teak, especially in farm forestry. In a study comparing the profitability of fast-growing plantation species with that of teak in Thailand, Niskanen *et al.* (1993) suggested several ways to overcome this constraint. The most efficient way would be to use a short rotation for teak (e.g. 25 years). Coppicing as a regeneration method in this species could also be more widely used. Special attention should be paid to the use of proper silvicultural methods, so as to improve the wood quality, which also would be positively affected by using agroforestry practices in on-farm teak growing. Using financial, economic or environmental economic profitability as criteria, these authors concluded that teak plantations, even with a short rotation, could

not compete with rubber plantation management in profitability; however, they performed relatively well in comparison to fast-growing forest plantations. Generally, the management practices in pure plantation are poor over agroforestry or farmlands. The comparative data pertaining to growth and timber yield or volume of teak in pure plantation and farmlands are scanty. Moreover, there is an urge to study the growth of teak in plantations and farmlands for implication of correct management practices to the farming community and make them to produce good quality teak timber. The main objective of the study was to compare the growth and productivity of teak grown in farmlands with pure plantations in the coastal region.

MATERIALS AND METHODS

An experiment was carried out in the Coastal Zone of Uttara Kannada district of Karnataka during 2014-15. The geographic location (latitude, longitude and altitude) of the teak plantations and farmlands in Coastal zone of Uttara Kannada district of Karnataka is given in table 1. Plantations and farmlands were selected in different locations of coastal zone with different age classes. Age of the plantation was recorded from the report of forest department of concern Range; however, age of the teak trees in farmlands was recorded from the farmers. In this study, growth and volume of teak trees were recorded from different age groups in tow different growing conditions. Factor 1 is considered as growing conditions as Pure plantation and Farmland, and Factor 2 is considered as age classes (four age classes, *viz.,* 5-10 yrs, 11-15 yrs, 16-20 yrs and 21-25 yrs). In each treatment, three trees were selected and following observations were recorded: GBH, total height, clear bole height, height of forking, spacing adopted, crown height, crown length, crown diameter, volume as per standard procedure (Chaturvedi and Khanna, 1994). Other observations like thinning regime, pruning, number of branches at first six meters, knots and any other management practices, if adopted, were also recorded in the study area. Biometric data were subjected to statistical analysis with two factorial Complete Randomized Design (CRD) following Gomez and Gomez (1984) and analysis of variance was constructed and used in interpretation of data.

RESULTS AND DISCUSSION

Among the two growing conditions *viz.,* pure plantations and farmlands, the growth of teak (height and diameter at breast height) was significantly higher in trees located at farmlands (11.95 m and 23.69 cm, respectively) as compared to pure plantations (11.60 m and 20.33 cm, respectively). The total volume of teak differed significantly among the two growing conditions. The teak volume was higher in farmlands (0.618 m^3) as compared pure plantations (0.429 m^3). The clear bole height (CBH) and timber volume of teak were significantly higher in farmlands (6.20 m and 0.335 m^3 respectively) as compared to pure plantations among the growing conditions studied. The crown height, crown length and crown diameter of teak were not differed significantly among the growing conditions studied (pure plantations and farmlands).

Among the four age classes, the growth of teak (height and diameter at breast height) was significantly higher in A_4: 21-25 years age class (14.72 m and 30.52 cm, respectively) followed by A_3: 16-20 years age class (13.72 m and 22.14 cm, respectively) and A_2: 11-15 years age class (10.38 m and 18.22 cm, respectively). The lowest growth of teak (height and diameter at breast height) was observed in A_1: 5-10 years age class (8.29 m and 17.14 cm). The interaction effect growth of teak between the growing conditions and age classes was significant (Table 2). The volume of teak was significantly higher in A_4: 21-25 years age class (1.093 m^3) followed by A_3: 16-20 years age class (0.535 m^3) and A_2: 11-15 years age class (0.271 m^3). The lowest volume of teak was recorded in A_1: 5-10 years age class (0.193 m^3). The interaction effect of volume of teak between the growing conditions and age classes was significant (Table 2). Clean bole height (CBH) was significantly higher in A_3: 16-20 years age class (7.72 m) followed by A_4: 21-25 years age class (7.25 m) and A_2: 11-15 years age class (3.96 m). The lowest clean bole height (CBH) of teak was recorded in A_1: 5-10 years age class (3.39). The timber volume of teak was significantly higher in A_4: 21-25 years age class (0.552 m^3) followed by A_3: 16-20 years age class (0.304 m^3) and A_2: 11-15 years age class (0.103 m^3). The lowest volume of teak was recorded in A_1: 5-10 years age class (0.081 m^3). The interaction effect of clear bole height (CBH) and timber volume of teak between the growing conditions and age classes were significant (Table 3). Crown height, crown length and crown diameter of teak were significantly higher in A_4: 21-25 years age class (9.71 m, 6.67 m and 4.87 m, respectively) followed by A_3: 16-20 years age class (9.53 m, 6.04 m and 4.49 m respectively) and A_2: 11-

Table 1. Geo-coordinates of study area (teak plantations and farmlands) in the coastal zone of Karnataka.

Location and Range	Latitude	Longitude	Altitude (m)
Kuntagani - Hiregutti	14° 39′ 002² N	074° 32′ 466² E	60
Chandavar- Kumta	14° 24′ 057² N	074° 28′ 426² E	45
Hodke Shirur – Honnavar	14° 22′ 155² N	074° 29′ 459² E	48
Kumta – Kumta Range	14° 25′ 230² N	074° 24′ 739² E	23

Table 2. Influence of age on height, diameter at breast height (DBH) and total volume of teak in pure plantation and on farmlands in Coastal Zone of Uttara Kannada district of Karnataka.

Age class (yrs)	Height (m)			DBH (cm)			Tree volume (m^3)		
	Pure plantation (G_1)	Farmlands (G_2)	Mean	Pure plantation (G_1)	Farmlands (G_2)	Mean	Pure plantation (G_1)	Farmlands (G_2)	Mean
A_1: 5-10	8.34	8.24	8.29	15.34	18.94	17.14	0.0154	0.232	0.193
A_2: 11-15	10.38	10.38	10.38	18.09	18.36	18.22	0.267	0.275	0.271
A_3: 16-20	13.39	14.05	13.72	20.15	24.14	22.14	0.428	0.643	0.535
A_4: 21-25	14.30	15.14	14.72	27.73	33.30	30.52	0.865	1.321	1.093
Mean	11.60	11.95		20.33	23.69		0.429	0.618	
For comparing		SEm ±	CD @ 5%		SEm ±	CD @ 5%		SEm ±	CD @ 5%
Growing Conditions (G)		0.07	0.21		0.08	0.26		0.01	0.02
Age classes (A)		0.09	0.29		0.12	0.36		0.01	0.03
Interaction (G x A)		0.14	0.42		0.17	0.51		0.01	0.04

Table 3. Influence of age on clean bole height, timber volume and height of forking of teak in different growing conditions.

Age class (yrs)	Clear bole height (m)			Height of forking (m)			Timber volume (m^3)		
	Pure plantation (G_1)	Farmlands (G_2)	Mean	Pure plantation (G_1)	Farmlands (G_2)	Mean	Pure plantation (G_1)	Farmlands (G_2)	Mean
A_1: 5-10	2.96	3.82	3.39	3.46	4.57	4.02	0.055	0.108	0.081
A_2: 11-15	3.74	4.18	3.96	4.41	4.71	4.56	0.096	0.111	0.103
A_3: 16-20	7.14	8.30	7.72	8.14	8.49	8.32	0.228	0.380	0.304
A_4: 21-25	6.00	8.51	7.25	6.67	8.89	7.78	0.363	0.742	0.552
Mean	4.96	6.20		5.67	6.67		0.185	0.335	
For comparing		SEm ±	CD @ 5%		SEm ±	CD @ 5%		SEm ±	CD @ 5%
Growing Conditions (G)		0.10	0.31		0.08	0.25		0.01	0.01
Age classes (A)		0.14	0.44		0.11	0.35		0.01	0.02
Interaction (G x A)		0.20	0.62		0.16	0.49		0.01	0.03

Table 4. Influence of age on crown height, crown length, crown diameter and number of branches of teak in different growing conditions.

Age class (yrs)	Crown height (m)			Crown length (m)			Crown diameter (m)			No. of branches		
	Pure plantation (G1)	Farmland (G2)	Mean	Pure plantation (G1)	Farm land (G2)	Mean	Pure plantation (G1)	Farm land (G2)	Mean	Pure plantation (G1)	Farm land (G2)	Mean
A1: 5-10	4.02	4.47	4.25	3.94	2.32	3.13	3.00	2.36	2.68	3.30	3.03	3.17
A2: 11-15	5.35	5.32	5.33	4.16	3.39	3.78	3.44	3.19	3.32	4.70	4.59	4.64
A3: 16-20	9.26	9.80	9.53	5.07	7.00	6.04	4.17	4.82	4.49	5.43	5.15	5.29
A4: 21-25	9.84	9.58	9.71	6.06	7.28	6.67	4.47	5.27	4.87	5.30	6.39	5.84
Mean	7.12	7.29		4.81	5.00		3.77	3.91		4.68	4.79	
For comparing		SEm ±	CD @ 5%		SEm ±	CD @ 5%		SEm ±	CD @ 5%		SEm ±	CD @ 5%
Growing Conditions (G)		0.13	NS		0.08	NS		0.08	NS		0.06	NS
Age classes (A)		0.19	0.58		0.12	0.352		0.12	0.36		0.09	0.27
Interaction (G x A)		0.27	NS		0.16	0.498		0.16	0.51		0.13	0.39

15 years age class (5.33 m, 3.78 m and 3.32 m respectively). The lowest observations on crown height, crown length and crown diameter of teak were recorded in A_1: 5-10 years age class (4.25 m, 3.13 m and 2.68 m, respectively). The interaction effect of crown height in teak between the growing conditions and age classes was insignificant. Whereas the interaction effects of crown length and crown diameter in teak between the growing conditions and age classes were significant (Table 4). The number of branches of teak was not significant among the two growing conditions. However, the number of branches of teak was significantly higher in A_4: 21-25 years age class (5.84) followed by A_3: 16-20 years age class (5.29) and A_2: 11-15 years age class (4.64). The lowest number of branches of teak was recorded in A_1: 5-10 years age class (3.17). The interaction effect of number of branches of teak between the growing conditions and age classes was significant (Table 4).

Among the two growing conditions studied, the height of forking in teak was significantly higher in farmlands (6.67 m) as compared pure plantations (5.67 m). Among the age classes studied, the height of forking in teak was significantly higher in A_3: 16-20 years age class (8.32 m) followed by A_4: 21-25 years age class (7.78 m) and A_2: 11-15 years age class (4.56 m). The lowest height of forking of teak was recorded in A_1: 5-10 years age class (4.02 m). The interaction effect of height of forking in teak between the growing conditions and age classes was significant (Table 3).

The growth performance of teak was better on farmlands as compared to plantations due to better management by the farming community. Teak under plantations had faced more competition for space, light, nutrients and any other resources available as compared teak on farmlands. Better growth of clear bole height and girth in teak on farmlands was attributed to early pruning (5-10 yrs age class) of lower branches by the farmers. It was noted that thinning regime was not applied in both the cases (plantations and farmlands). But some of the trees on farm bunds were randomly removed / harvested as small poles (timber) at an age of 11-15 years without any thumb rule by the farmers (intermediate yield) whenever they required for their self utilization, especially for agricultural implements and household purpose.

A study conducted on smallholder teak plantations in two villages in Central Java: Silvicultural activity and stand performance revealed that (A total of 66 farmers were interviewed and 121 inventory plots measured) most of the usual silvicultural practices were implemented, although thinning was rarely conducted. In older plantations (>5 to 7 years old), low growth was most likely due to a lack of thinning. Farmers allocated minimum inputs for silvicultural management, mainly because teak was not one of the farmers' main income sources. None of the farmers' socio-economic and per-

ceptional characteristics influenced their silvicultural management activity. In order to improve teak growth and quality, farmers need motivated and skilled extension officers to advise them in site selection and in thinning and pruning techniques (Kallio *et al.,* 2012).

The integration of community-based or individual teak management with wood processing and marketing is also a distinct feature. However, there is an obvious need to develop new silvicultural guidelines and offer technical assistance for teak cultivation, which would then guarantee a better quality of teak products (Roshetko *et al.,* 2013). The plantations managed by smallholder have the potential to create sustainable economic, environmental and social benefits for their growers if trees are integrated in the production system following well-established local practices. Benefits seem to be accrued especially if the costs of tree planting and management can be reduced; farmers also have the ability to quickly adapt to new marketing opportunities (Pokorny *et al.,* 2010).

The present study showed that teak tree grown in farmlands performed better than pure plantation. However, it is necessary to provide proper guide of planting, protection, silviculture management like fertilizer application, pruning and thinning, to the farmers to attain higher growth and productivity potential of teak under different agroforestry systems. Furthermore, a recent guide for policy-makers (FAO, 2002) takes this into consideration and provides an outline of how policy can support agroforestry and how new models for teak growing could also be achieved. A feasible approach would be to highlight planted trees as components of sustainable food production systems and providers of economic, environmental and social benefits and services, primarily to the rural population but also for countries.

Conclusion

The present study concluded that the teak performed better on farmlands as compared to plantations due to better management by the farming community. Better growth of clear bole and girth in teak on farmlands was attributed to early pruning (5-10 yrs age class) of lower branches by the farmers. But some of the trees on farm bunds were randomly removed / harvested as small poles (timber) at an age of 11-15 years without any thumb rule by the farmers (intermediate yield) whenever they required for their self utilization for agricultural implements or any other household purpose. So it can be suggested that pruning (5-10 yrs) and thinning (5-10 and 10-15 yrs) are the important tools for better silviculutral management for commercial growth of teak (girth and clear bole) to fetch more economic value in the market. Trenching along the teak rows on farm bund helped trees for soil working, loosening of soil, moisture conservation, weed control that would influenced positively on tree growth.

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