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# Growth status and site quality of different seed production areas of teak (*Tectona grandis* L. f) in Karnataka, India

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**Abstract** In the present study 20 SPAs of teak distributed in southern, central and northern parts of Karnataka, India are selected. Phenotypic parameters of standing trees of different SPAs were recorded. Further, seed yield was also recorded and compared with site quality and stand growth parameters. Result showed that there was a greater variation among SPAs for phenotypic growth characters as well as site quality. The overall growth of SPAs of Madikeri zone (Southern region) was found to be superior with respect to tree height, clear bole height and DBH. SPAs belonged to Dandeli (Northern region) recorded more DBH and nearly round stem. SPAs of Yallapur seed zone showed comparatively less growth over Madikeri zone. SPA of Dandeli zone recorded the more tree volume and top height, followed by SPA of Madikeri zone. Considering site quality of different SPAs, all the studied SPAs of Karnataka are growing under relatively poor site conditions. Sixteen out of twenty SPAs, nearly 80% were growing in areas with site quality classes IV and V. Interestingly, none of the studied SPAs belonged to either class I or II. Association study showed that tree height (r=0.403) and clear bole height (r=0.412) showed positive relationship with seed yield. Furthermore, site quality showed a weak positive relationship with seed yield ($R^2$=0.052) among SPAs indicating poor site quality could be a major factor for low seed yield. It is concluded that SPAs of Madikeri and Dandeli zones performed better in growth and stem form. Therefore, it is suggested to collect quality seeds from these seed zones.

**Keywords:** Fruit yield, Phenotypic traits, Seed production area, *Tectona grandis*

## INTRODUCTION

Teak is one of the commercial important hardwood species of the World, which is distributed naturally in India and south-east Asian region. India is one of the countries that producing quality teak timber having good specific gravity, strength and durability (Tewari, 1992). Due to huge demand of quality teak wood, the teak growing area has been extended extensively. According to FAO (food and agricultural organization) report, total area under teak forests in India was 1.34 million ha representing 14.13 per cent industrial wood production. Recently, it is reported that the existing area under teak plantation is about 2.6 million ha with 12.8 million $m^3$ sustainable yield (ITTO, 2009; Blaser *et al.,* 2011). Therefore, quality planting material is very essential to achieve good quality timber at the earliest.

To produce superior seeds in sufficient quantity, teak improvement programme was initiated in 1962 and proposal for establishment of seed orchards (SOs) and seed production areas (SPAs) in teak growing areas of the country was proposed (Bhat *et al.,* 2005). The annual planting target of this species in the country is more than 50,000 ha, which are raised through different seed sources like SPA (50%), clonal orchard (25%) and unimproved plantation (25%) (Subramanian *et al.,* 2000; Katwal *et al.,* 2003). This clearly shows that there is an ample demand for quality seed materials for plantation programme. Therefore, the present study was undertaken to study the status of growth, site quality and seed yield among 20 SPAs in Karnataka, India.

## MATERIALS AND METHODS

Total 20 seed production areas (SPAs) distributed in four different ecological zones *viz.,* Dandeli (7 SPAs *viz.,* $D_1$ to $D_7$), Yallapur (4 SPAs *viz.,* $Y_1$ to $Y_4$), Shimoga (4 SPAs *viz.,* $S_1$ to $S_4$) and Madikeri (5 SPAs *viz.,* $M_1$ to $M_5$) of Karnataka were selected (Table 1). Location and geographical details of individual SPA are given in table 1. These seed production areas are established by selecting improved plantation in which inferior individuals are removed and superior genotypes are maintained for intermate to produce quality seeds in large quantity.

In each SPA, three sample plots of size 40 × 40 m (approximately 2 % sampling intensity) were laid out randomly by providing a minimum of 150-m distance

from the boundary to avoid the edge/ boundary effect. Tree density and phenotypic characters like tree height, clear bole height, girth at breast height (GBH) and crown diameter were recorded for all marked individuals within a plot. Stem straightness and its roundness of stem were also recorded following Rao *et al.* (2001). Further, individual tree volume was calculated using following formula: ÖV= - a+ bD (r= 0.9782, df = 2010), where V is volume ($m^3$), D is over-bark Diameter Breast Height (DBH; m), a = 0.5514 (regression constant) and b = 3.859 (regression co-efficient) (Cheturvedi and Khanna, 1994).

Top height (m) was determined using standard procedure to identify the site quality of individual SPA using all India site quality table for teak (Tewari, 1992). The age of SPA considered for the present study varied from 40 to 79 years. Hence, all the SPAs were grouped into four age classes *viz.*, a) 1926-35, b) 1936-45, c) 1946-55 and d) 1956-65 to identify age variation, if any for all phenotypic characters. The data were subjected to statistical analysis using standard statistical software (mSTAT-C) following randomized block design (RBD). Here, SPA is considered as experimental treatment and individual sample plot (N=3) as replicated value. To study the influence of stand growth characters on seed yield, a simple correlation analysis was done.

## RESULTS AND DISCUSSION

Result showed that there was no significant difference among four age classes for tree height, bole height, diameter at breast height and stem form (Table 2). This could be due to growth convergence among individuals after certain age in long rotation species. For instance, Kumar and Srinivasa (2005) reported the growth convergence in teak trees. In their study, growth patterns of 168 trees from three sites located in Dandeli zone *viz.*, Virnoli, Bhagavati and Barchi, were analyzed after classifying them into four cohorts, based on the radial growth accumulated over the initial 20 years. They have shown that growth rates varied significantly among cohorts up to 15 years, then growth converged towards the end of the juvenility *i.e.*, between 16-20 years. It revealed that irrespective of age of the trees and size of the trees, growth rate converges towards the end of the juvenile phase (Bhat *et al.*, 2001; Kumar and Srinivasa, 2005). In the study, crown diameter showed variation among different age classes and it varied from 4.41 to 6.00 m (Table 2).

Tree density varied significantly among SPAs that ranged from 113 to 267 trees per hectare. It is recommended that there should be 150 individuals per ha to obtain large quantity of seed yield in seed production areas (Rao, 2005. However, nine SPAs

**Table 1.** Details of study area (seed production areas).

| SPA | Seed zones/ SPAs | SPA Code | Extent (ha) | Year of plantation | Tree density ($ha^{-1}$) | Latitude (N) | Longitude (E) | Altitude (msl) |
|---|---|---|---|---|---|---|---|---|
| | Dandeli seed zone | | | | | | | |
| 1 | Hudsa | $D_1$ | 20.0 | 1927 | 115 | 15º 08' | 74º 31' | 510 m |
| 2 | Bhagavati | $D_2$ | 50.0 | 1928 | 138 | 15º 09' | 74º 43' | 422 m |
| 3 | Janata Colony | $D_3$ | 20.0 | 1950 | 113 | 15º 13' | 74º 36' | 513 m |
| 4 | Kulagi | $D_4$ | 10.0 | 1950 | 173 | 15º 09' | 74º 38' | 538 m |
| 5 | Veerampalli Plot –1 | $D_5$ | 8.8 | 1951 | 133 | 15º 13' | 74º 35' | 599 m |
| 6 | Veerampalli Plot –2 | $D_6$ | 11.2 | 1952 | 113 | 15º 13' | 74º 35' | 562 m |
| 7 | Virnoli | $D_7$ | 20.0 | 1957 | 154 | 15º 13' | 74º 36' | 513 m |
| | Madikeri seed zone | | | | | | | |
| 8 | Moovakal –1 | $M_1$ | 34.4 | 1930 | 150 | 12º 15' | 75º 59' | 899 m |
| 9 | Moovakal –2 | $M_2$ | 27.0 | 1931 | 173 | 12º 15' | 75º 59' | 918 m |
| 10 | Moovakal –3 | $M_3$ | 30.0 | 1932 | 210 | 12º 15' | 75º 59' | 870 m |
| 11 | Devamachi –1 | $M_4$ | 25.0 | 1936 | 177 | 12º 16' | 75º 59' | 933 m |
| 12 | Devamachi –2 | $M_5$ | 25.0 | 1937 | 152 | 12º 16' | 75º 59' | 921 m |
| | Shimoga seed zone | | | | | | | |
| 13 | Sannivasa | $S_1$ | 13.0 | 1941 | 206 | 14º 04' | 75º 19' | 696 m |
| 14 | Gaddemane | $S_2$ | 23.0 | 1956 | 183 | 14º 05' | 75º 16' | 655 m |
| 15 | Konehosur | $S_3$ | 22.0 | 1959 | 208 | 14º 05' | 75º 17' | 711 m |
| 16 | Halkuni | $S_4$ | 24.0 | 1963 | 127 | 14º 05' | 75º 21' | 638 m |
| | Yallapur seed zone | | | | | | | |
| 17 | Gunjavati –1 | $Y_1$ | 21.0 | 1937 | 267 | 14º 59' | 74º 54' | 500 m |
| 18 | Gunjavati –2 | $Y_2$ | 20.0 | 1937 | 146 | 14º 59' | 74º 54' | 508 m |
| 19 | Kanderayana Koppa -1 | $Y_3$ | 15.0 | 1941 | 202 | 15º 00' | 74º 51' | 585 m |
| 20 | Kanderayana Koppa -2 | $Y_4$ | 15.0 | 1964 | 156 | 15º 00' | 74º 51' | 585 m |

**Table 2.** Variation among four age groups with respect to phenotypic characteristics.

| Age Classes | Tree height (m) | Bole height (m) | DBH (cm) | Crown diameter (m) | Stem form | |
|---|---|---|---|---|---|---|
| | | | | | Straight | Round |
| 1926-35 (n= 5) | 20.89 | 10.56 | 35.67 | 4.41 | 4.68 | 6.51 |
| 1936-45 (n= 6) | 22.42 | 10.08 | 32.96 | 5.78 | 4.64 | 5.41 |
| 1946-55 (n= 4) | 20.99 | 8.64 | 39.15 | 5.38 | 5.87 | 7.16 |
| 1956-65 (n= 5) | 19.07 | 7.62 | 30.83 | 6.00 | 5.13 | 6.06 |
| Overall mean | 20.92 | 9.29 | 34.33 | 5.41 | 5.02 | 6.19 |
| SD | 2.35 | 1.69 | 0.18 | 0.86 | 0.89 | 1.15 |
| P-level | NS | NS | NS | 0.04 | NS | NS |

**Table 3.** Variation in phenotypic characters and site quality among SPAs of teak.

| SPA Code | Tree height (m) | Bole height (m) | DBH (cm) | Crown diameter (m) | Stem form | | Tree volume ($m^3$) | Top height (m) | Site quality index |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Straight | Round | | | |
| $D_1$ | 23.49 | 12.26 | 39.25 | 5.36 | 5.00 | 6.67 | 0.967 | 24.10 | IV |
| $D_2$ | 19.20 | 7.91 | 38.66 | 5.18 | 5.75 | 7.43 | 0.953 | 19.55 | V |
| $D_3$ | 16.36 | 6.51 | 28.69 | 4.26 | 5.43 | 6.28 | 0.729 | 17.89 | V |
| $D_4$ | 23.39 | 9.44 | 40.69 | 5.11 | 5.97 | 7.46 | 0.998 | 24.49 | III |
| $D_5$ | 21.31 | 9.61 | 41.69 | 5.54 | 6.03 | 7.34 | 1.023 | 21.71 | IV |
| $D_6$ | 22.91 | 8.93 | 45.64 | 6.60 | 6.06 | 7.56 | 1.094 | 21.92 | IV |
| $D_7$ | 18.94 | 7.05 | 33.69 | 4.87 | 5.16 | 6.94 | 0.852 | 19.27 | IV |
| $M_1$ | 19.96 | 10.45 | 36.32 | 4.29 | 4.78 | 6.33 | 0.903 | 21.07 | IV |
| $M_2$ | 19.87 | 10.30 | 28.94 | 3.46 | 3.99 | 6.04 | 0.734 | 21.56 | IV |
| $M_3$ | 21.95 | 11.89 | 35.31 | 3.78 | 3.89 | 6.06 | 0.888 | 23.15 | IV |
| $M_4$ | 26.21 | 13.28 | 39.03 | 4.34 | 4.86 | 6.45 | 0.968 | 27.08 | III |
| $M_5$ | 26.08 | 12.66 | 44.10 | 5.59 | 6.15 | 6.21 | 1.064 | 25.41 | IV |
| $S_1$ | 19.05 | 8.02 | 35.60 | 6.78 | 6.23 | 6.62 | 0.835 | 21.31 | IV |
| $S_2$ | 19.25 | 6.88 | 32.98 | 5.88 | 6.82 | 7.09 | 0.835 | 20.32 | IV |
| $S_3$ | 19.46 | 8.24 | 34.96 | 6.84 | 7.04 | 6.20 | 0.878 | 22.68 | III |
| $S_4$ | 18.06 | 7.58 | 26.04 | 7.00 | 4.67 | 6.40 | 0.655 | 19.14 | IV |
| $Y_1$ | 20.24 | 8.24 | 28.26 | 6.08 | 4.94 | 3.09 | 0.708 | 22.55 | IV |
| $Y_2$ | 20.25 | 8.97 | 29.75 | 6.06 | 3.91 | 6.08 | 0.757 | 21.06 | IV |
| $Y_3$ | 19.64 | 8.38 | 26.40 | 5.41 | 5.04 | 6.91 | 0.673 | 20.25 | IV |
| $Y_4$ | 21.62 | 9.17 | 30.85 | 6.13 | 4.09 | 6.81 | 0.785 | 22.57 | III |
| Mean | 20.76 | 9.25 | 34.28 | 5.39 | 5.28 | 6.36 | 0.852 | 21.85 | - |
| SD | 3.59 | 3.68 | 11.91 | 2.8 | 2.91 | 2.63 | 0.21 | 2.36 | - |
| P-level | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | < 0.001 | <0.001 | - |

recorded more tree density than the recommended number (Table 1). In this study, few inferior individuals infested by trunk borer were also recorded in some of the SPAs. Therefore, it is suggested to remove such inferior individuals in SPA through complete survey to improve the status of seed quality (Gunaga, 2008).

Result showed that there was a significant variation among SPAs, where tree height ranged from 16 ($D_3$) to 26 m ($M_4$ and $M_5$). Similarly, SPAs such as $M_4$, $M_5$ and $D_1$ recorded highest clear bole height of about 13m and it was the least in SPAs like $S_2$ and $D_3$ (about 7 m). Diameter at breast height (DBH) varied from 26 ($S_4$ and $Y_3$) to 45 m ($D_6$ and $M_5$). However, the crown diameter was found to be highest in SPA of $S_3$ (6.84m) and $S_1$ (6.78 m) and it was lowest in $M_2$ (3.4 m).

The overall growth of SPAs of Madikeri zone (Southern region) was found to be superior with respect to tree height, clear bole height and DBH, where Madikeri zone receives more rainfall as compared to other zones (Table 3). However, SPAs belonged to Dandeli (Northern region) recorded more DBH and nearly round stem. This may be due to less stocking in SPAs of Dandeli. Yallapur seed zone belonged to low rainfall region of Karnataka. Due to this, the overall

growth of trees in different SPAs recorded the lowest values. Tree volume also showed significant variation among SPAs and it varied from 0.655 to 1.0 $m^3$ $tree^{-1}$ with an overall mean of 0.852 $m^3$ $tree^{-1}$ (Table 3). Top height is one of the important parameters used to assess the site quality, where it ranged from 17.89 to 25.41 m. SPAs of Dandeli zone recorded the more tree volume and top height, followed by Madikeri zone. However, Yallapur seed zone recorded the lowest volume (0.724 $m^3$).

Such information among SPAs of teak in India is scanty, except Prabhu (2007), who has undertaken study on evaluation of SPAs of Kerala for quality seed yield. He reported that tree height, clear bole height, diameter and straightness of stem showed significant variation among 38 SPAs with medium to poor seed yield. Strong seed zonal variation for these traits also recorded, where SPAs of Nilambur and Parambikulam zones performed better than SPAs of Konni, Achencoil and Waynad. Variations for tree height, bole height and stem diameter during early to juvenile growth stage in plantations have been reported (Rawat *et al.*, 1992; Bagachi, 1995).

The productivity of forest lands is largely defined in terms of site quality, which is measured by the maximum timber yield by the land in a given time (Katwal *et al.*, 2003). Site quality not only determines the production of timber or other NTFP products, but also the seed yield. It is known that trees growing in fertile soil produce more flowering than trees growing in poor or infertile soil. The present study showed that the existing SPAs of Karnataka were growing under relatively poor site conditions (Table 2). Sixteen out of twenty SPAs, nearly 80 percent, were growing in areas with site quality classes IV and V and none of them belonged to either class I or II (Table 2). Association study showed that there was a positive but weak relationship between site quality and seed yield ($R^2$=0.052) indicating poor site quality results in low seed yield. Further, it is also reported that seed yield may also affected by several factors like flowering synchrony, prevailing rainfall and flowering season and temperature conditions of the site (Gunaga and Vasudeva, 2005). Interestingly, tree height (r=0.403; significant at 1%) and clear bole height (r=0.412; significant at 1%) showed positive significant relationship with seed yield. Therefore, growth of stand is also important to get quality seeds in large quantity.

Overall result showed that there is a necessity to undertake silvicultural interventions like manuring, fertilizer application, soil working, spraying of growth hormones like Paclobutrozol to improve the seed production among SPAs (Gunaga and Vasudeva, 2005). Moreover, it is suggested to select a best plantation that growing under better quality site for further conversion of plantation into a seed stand or SPA.

## Conclusion

The main objective of SPA is to produce quality seeds in large quantity. It is recorded that tree height and clear bole height showed positive influence on fruit yield. The existing SPAs varied with respect to tree growth and site quality. Madikeri followed by Dandeli zone performed better in terms of growth and stem form. Interestingly, most of the SPAs studied are growing under poor quality sites (III to V). Therefore, silvicultural intervention like soil working, fertilizer application and hormonal spraying may help in improving the seed quality and quantity in the SPA.

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