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

Rajesh P. Gunaga¹*, Avinash M. Kanfade² and R. Vasudeva³

¹College of Forestry, Narsar Agricultural University, Navsari (Gujarat), INDIA
²Research Coordinator, Institute of wood Science and Technology, Bangalore (Karnataka), INDIA
³College of Forestry, University of Agricultural Sciences, Sirsi Campus (Karnataka), INDIA

*Corresponding authors. E-mail: rpgunaga@gmail.com

Received: June 27, 2014; Revised received: August 28, 2014; Accepted: October 13, 2014

**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 (R²=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 m³ 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., D₁ to D₇), Yallapur (4 SPAs viz., Y₁ to Y₄), Shimoga (4 SPAs viz., S₁ to S₄) and Madikeri (5 SPAs viz., M₁ to M₅) 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...
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^2) | Latitude (N) | Longitude (E) | Altitude (msl) |
|--------------|------------------|----------|-------------|-------------------|--------------------|--------------|---------------|----------------|
| Dandeli seed zone |                  |          |             |                   |                    |              |               |                |
| 1            | Hudsa            | D_1      | 20.0        | 1927              | 115                | 15°08'       | 74°31'       | 510 m          |
| 2            | Bhagavati        | D_2      | 50.0        | 1928              | 138                | 15°09'       | 74°43'       | 422 m          |
| 3            | Janata Colony    | D_3      | 20.0        | 1950              | 113                | 15°13'       | 74°36'       | 513 m          |
| 4            | Kulagi           | D_4      | 10.0        | 1950              | 173                | 15°09'       | 74°38'       | 538 m          |
| 5            | Veerampalli Plot –1 | D_5     | 8.8         | 1951              | 133                | 15°13'       | 74°35'       | 599 m          |
| 6            | Veerampalli Plot –2 | D_6     | 11.2        | 1952              | 113                | 15°13'       | 74°35'       | 562 m          |
| 7            | Virnoli          | D_7      | 20.0        | 1957              | 154                | 15°13'       | 74°36'       | 513 m          |
| Madikeri seed zone |                  |          |             |                   |                    |              |               |                |
| 8            | Moovakal –1     | M_1      | 34.4        | 1930              | 150                | 12°15'       | 75°59'       | 899 m          |
| 9            | Moovakal –2     | M_2      | 27.0        | 1931              | 173                | 12°15'       | 75°59'       | 918 m          |
| 10           | Moovakal –3     | M_3      | 30.0        | 1932              | 210                | 12°15'       | 75°59'       | 870 m          |
| 11           | Devamachi –1    | M_4      | 25.0        | 1936              | 177                | 12°16'       | 75°59'       | 933 m          |
| 12           | Devamachi –2    | M_5      | 25.0        | 1937              | 152                | 12°16'       | 75°59'       | 921 m          |
| Shimoga seed zone |                  |          |             |                   |                    |              |               |                |
| 13           | Sannivasa       | S_1      | 13.0        | 1941              | 206                | 14°04'       | 75°19'       | 696 m          |
| 14           | Gaddemane       | S_2      | 23.0        | 1956              | 183                | 14°05'       | 75°16'       | 655 m          |
| 15           | Konkohsur       | S_3      | 22.0        | 1959              | 208                | 14°05'       | 75°17'       | 711 m          |
| 16           | Halkuni         | S_4      | 24.0        | 1963              | 127                | 14°05'       | 75°21'       | 638 m          |
| Yallapur seed zone |                  |          |             |                   |                    |              |               |                |
| 17           | Gunjavati –1    | Y_1      | 21.0        | 1937              | 267                | 14°59'       | 74°54'       | 500 m          |
| 18           | Gunjavati –2    | Y_2      | 20.0        | 1937              | 146                | 14°59'       | 74°54'       | 508 m          |
| 19           | Kandarayana Koppa –1 | Y_3   | 15.0        | 1941              | 202                | 15°00'       | 74°51'       | 585 m          |
| 20           | Kandarayana Koppa –2 | Y_4   | 15.0        | 1964              | 156                | 15°00'       | 74°51'       | 585 m          |
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 (D3) to 26 m (M4 and M5). Similarly, SPAs such as M4, M5 and D1 recorded highest clear bole height of about 13 m and it was the least in SPAs like S2 and D3 (about 7 m). Diameter at breast height (DBH) varied from 26 (S4 and Y3) to 45 m (D6 and M5). However, the crown diameter was found to be highest in SPA of S3 (6.84 m) and S1 (6.78 m) and it was lowest in M2 (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

| SPA Code | Tree height (m) | Bole height (m) | DBH (cm) | Crown diameter (m) | Stem form | Tree volume (m³) | Top height (m) | Site quality index |
|----------|----------------|----------------|----------|--------------------|-----------|-----------------|---------------|-------------------|
| D1       | 23.49          | 12.26          | 39.25    | 5.36               | Straight  | 5.00            | 6.67          | 0.967             | IV                |
| D2       | 19.20          | 7.91           | 38.66    | 5.18               | Round     | 5.75            | 7.43          | 0.953             | V                 |
| D3       | 16.36          | 6.51           | 28.69    | 4.26               | Straight  | 5.43            | 6.28          | 0.729             | 17.89             |
| D4       | 23.39          | 9.44           | 40.69    | 5.11               | Round     | 5.97            | 7.46          | 0.998             | 24.49             |
| D5       | 21.31          | 9.61           | 41.69    | 5.54               | Straight  | 6.03            | 7.34          | 1.023             | 21.71             |
| D6       | 22.91          | 8.93           | 45.64    | 6.60               | Round     | 6.06            | 7.56          | 1.094             | 21.92             |
| D7       | 18.94          | 7.05           | 33.69    | 4.87               | Round     | 5.16            | 6.94          | 0.852             | 19.27             |
| M1       | 19.96          | 10.45          | 36.32    | 4.29               | Round     | 4.78            | 6.33          | 0.903             | 21.07             |
| M2       | 19.87          | 10.30          | 28.94    | 3.46               | Round     | 3.99            | 6.04          | 0.734             | 21.56             |
| M3       | 21.95          | 11.89          | 35.31    | 3.78               | Round     | 3.89            | 6.06          | 0.888             | 23.15             |
| M4       | 26.21          | 13.28          | 39.03    | 4.34               | Round     | 4.86            | 6.45          | 0.968             | 27.08             |
| M5       | 26.08          | 12.66          | 44.10    | 5.59               | Round     | 6.15            | 6.21          | 1.064             | 25.41             |
| S1       | 19.05          | 8.02           | 35.60    | 6.78               | Round     | 6.23            | 6.62          | 0.835             | 21.31             |
| S2       | 19.25          | 6.88           | 32.98    | 5.88               | Round     | 6.82            | 7.09          | 0.835             | 20.32             |
| S3       | 19.46          | 8.24           | 34.96    | 6.84               | Round     | 7.04            | 6.20          | 0.878             | 22.68             |
| S4       | 18.06          | 7.58           | 26.04    | 7.00               | Round     | 4.67            | 6.40          | 0.655             | 19.14             |
| Y1       | 20.24          | 8.24           | 28.26    | 6.08               | Round     | 4.94            | 3.09          | 0.708             | 22.55             |
| Y2       | 20.25          | 8.97           | 29.75    | 6.06               | Round     | 3.91            | 6.08          | 0.757             | 21.06             |
| Y3       | 19.64          | 8.38           | 26.40    | 5.41               | Round     | 5.04            | 6.91          | 0.673             | 20.25             |
| Y4       | 21.62          | 9.17           | 30.85    | 6.13               | Round     | 4.09            | 6.81          | 0.785             | 22.57             |
| Mean     | 20.76          | 9.25           | 34.28    | 5.39               | Round     | 5.28            | 6.36          | 0.852             | 21.85             |
| SD       | 3.59           | 3.68           | 11.91    | 2.8                | Round     | 2.91            | 2.63          | 0.21              | 2.36              |
| P-level  | <0.001         | <0.001         | <0.001   | <0.001             | Round     | <0.001          | <0.001        | <0.001             | <0.001             |

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 | Tree volume (m³) | Top height (m) | Site quality index |
|-------------|----------------|----------------|----------|--------------------|-----------|-----------------|---------------|-------------------|
| 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.
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, Achencol 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 NTFPs 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. 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.

**ACKNOWLEDGEMENTS**

This study is a part of Ph. D. (Forestry) thesis submitted by the first author to the Forest Research Institute and University, Dehradun, India. Authors are thankful to Karnataka Forest Department for permission to collection teak germplasm from different SPAs.

**REFERENCES**

Bagachi, S.K. (1995). Selection differential and predicted genetic gain in Tectona grandis Linn. f. Ind. For., 121: 482-490.

Bhat, K. M., Nair, K. K. N., Bhat, K. V., Muralidharan, E. M. and Sharma, J. K. (2003). Quality timber products of teak from sustainable forest management. Published by Kerala Forest Research Institute, Peechi, India, pp 320.

Bhat, K. M., Priya, P. B. and Rugmini, P. (2001). Characterization of juvenile wood in teak. Wood Sci. Tech., 34: 517-532.

Blaser, J., Sarre, A., Poore, D. and Johnson, S. (2011). Status of tropical forest management- 2011. ITTO Technical Series No 38. International Tropical Timber Organization, Yokohama, Japan.

Cheturvedi, A. N. and Khanna, L. S. (1994). Forest Mensuration, IBD, Dehradun, pp 403.

Gunaga, R. P. (2008). Evaluation of seed production areas of teak in Karnataka for their seed quality and nursery performance. Ph.D. thesis (Forestry) submitted to FRI, Dehradun, pp 182.

Gunaga, R. P. and Vasudeva, R. (2005). Causes for low fruit production in Clonal seed orchards of Teak. In: Bhat, K.M., Nair, K.K.N., Bhat, K.V., Muralidharan, E.M. and Sharma, J.K. (Eds.), Quality Timber Products of Teak from Sustainable Forest Management. Published by KFRI, Poonchi, India, pp 352-358.

ITTO (2009). STCP Engenharia de Projetos Ltda. Encouraging industrial forest plantations in the tropics: Report of a global study. ITTO Technical Series 33, ITTO, Yokohama, Japan.

Katwal, R. P. S., Srivastva, P. K., Kumar, S. and Jeeva, V. (2003). State of forest genetic resources conservation and management in India. In: Forest genetic resources working papers, working paper FGR/65E. forest resources development service, Forest Resources Division. FAO, Rome, pp 36.

Kumar, A. N. A. and Srinivasa, Y. B. (2005). Stand level radial growth rate pattern reveals ‘Growth Convergence’ in Tectona grandis L.f. In: Bhat, K. M., Nair, K. K. N., Bhat, K. V., Muralidharan, E. M., Sharma, J. K. (Eds.) Quality timber products of teak from sustainable forest management, Published by KFRI, Peechi, India, pp 523-529.
Prabhu, N. H. (2007). Evaluation of seed production areas of teak in Kerala for their seed quality and nursery performance in root trainers. Ph.D. thesis (Forestry) submitted to FRI, Dehradun, pp 164.

Rao, P. S. (2005). Status of teak in Andhra Pradesh, India. In: Bhat, K. M., Nair, K. K. N. Bhat, K. V., Muralidharan, E.M. and Sharma, J.K. (Eds.). Quality Timber Products of Teak from Sustainable Forest Management, Published by KFRI, Peechi. pp 31-44.

Rao, P. S., Venkaiah, K., Murali, V., Murthi, S. S. N. and Sattar, S. A. (2001). Evaluation of international teak provenance trial plot in North-East Andhra Pradesh. Ind. For., 127: 415-422.

Rawat, M. S., Uniyal, D. P. and Vakshasya, R. K. (1992). Variation in the model teak seed orchard. New Forest, Dehra Dun. Ind. J. For., 118(1-4): 60-65.

Subramanian, K., Mandal, A. K., Ram Babu, N., Chandamannil, M. and Nagarajan, B. (2000). Site, technology and productivity of teak plantations in India. In: Enters, T. and Nair, C.T.S. (Eds.) Site, Technology and Productivity of Teak Plantations. FORSPA publication No. 24/2000. FAO, Bangkok, pp 51-68.

Tewari, D. N. (1992). A Monograph on Teak (Tectona grandis Linn.f.). International Book Distributors, Dehra Dun, India, pp 479.