Review Article

Optimization of Teak Growth, Productivity and Wood quality through Implementation of Sound Silvicultural Techniques - A Review

Abstract

Teak (*Tectonagrandis*L.f.) is one of the most important tropical hardwood tree species in world and popularly known as "King of timbers". It is the most valued species for structural and non-structural applications and has commanded a premium price in global market. With diminishing supply of timber from the natural forests, attention has now been shifted considerably towards fast grown plantation species to meet the timber deficit. The variation in the growth, quality and distribution of teak is mostly dictated by soil-site characteristics. Natural teak forests occur on black and red soils developed from the underlying rock *viz*. sandstone, granite-gneiss and basalt.The shift in teak plantation management from government sectors to private farm lands and plantation companies led to intensive management of teak plantations and consequent reduction in rotation age of plantation.Silviculture techniques act as a tool for commercial tree farming to attain the maximum growth and productivity. Stand management practices such as plant spacing, thinning and pruning affect diameter, height growth, commercial volume of timber and wood quality. The implementation of thinning and pruning regimes in the clonal teak plantation as part of intensive silvicultural techniques helps to improve the growth and productivity of teak plantation. Thinning and pruning regimes can enhance the mechanical properties without having a serious alteration in the physical properties of clonal teak wood. Lower wood density and durability of the short rotation teak compared to the long rotation teak will restrict its utilization to some extent for both indoor and outdoor applications.With the adoption of sound silvicultural practices specific to the species, the prodcutivity can be enhanced without comprimising the quality of the produce.

Keywords: Silvicultural practices, Thining, Pruning, Productivity and Wood quality

Introduction:

Teak is regarded as the 'King of Timbers' due to its commercial value for its timber, wood quality and aesthetics. Because of its high durability, it can be used for a wide variety of indoor and outdoor purposes. The presence of oil in the teakwood makes it resistant to insects, fungi and termites and helps to withstand extended exposure to water as well as chemicals. This ring-porous wood species is highly demanded for its natural durability, aesthetic properties and mechanical resistance (Ramasamy*et al*. 2021).

The global teak wood packaging market is expected to account for USD 7.87 billion by 2031 from 4.13 USD of 2023 at a current annual rate of growth of 8.4 per cent(Anon, 2024). In 2022, the top exporters of rough teak wood were Ecuador ($72.2M), Ghana ($61.2M), Panama ($48.2M), Brazil ($20.8M) and Costa Rica ($15.4M). In 2022, the top importers of rough teak wood were India ($247M), Vietnam ($9.31M), China ($8.26M), Netherlands ($2.32M) and Italy ($1.09M)(Anon, 2022).Teak is found naturally in south and south-eastAsia mainly in India, Myanmar, Indonesia, Philippines, Malaysia, Nepal, *etc.* The commercial planting of teak started around the year 1700 in Malaysia and in the year 1842 in India (Shankar, 2022). Natural teak forests were estimated to cover 29.035 mi. ha in India, Laos, Myanmar and Thailand. The majority of teak plantations are in Asia (80%) followed by Africa (13%) and Latin America (7%). Realizing the potential of teak in the international market, teak plantations have expanded from their natural habitats rapidly (Haridas, 2017).

With diminishing supply of timber from the natural forests, attention has now been shifted considerably towards fast grown plantation species to meet the timber deficit. However, productivity of such short-rotation plantation species needs to be increased and monitored periodically(Shukla and Viswanath, 2014).Out of estimated 187 mi ha of global forest plantations, teak constitutes about 5.7 mi ha which is approximately two-third of the world's highquality tropical hardwood plantation(Anon, 2000).Massive plantation programmes, with the involvement of the private sector were started in India as well as outside in the past two decades with an aim to maximise timber production per unit land area through genetic selection and intensive silvicultural techniques that accelerate tree growth for early harvesting (Bhat and Indira, 1997). The rapid expansion of teak outside its natural habitats has necessitated identification and development of specific genotypes to meet the specific site requirements and promote optimal growth. Availability of good quality planting material along with adoption of scientifically validated approaches are essential for successful establishment of teak plantations outside their natural habitats (Chelliah*et al.* 2021).

Comment [CP1]: It's been 24 years since this appointment, the figures may have changed, please update the source of consultation

Young trees exhibit vigorous growth as trees grow they start to compete with each other for light and space. The cross section of a young tree will have wide growth rings and its diameter expands quickly. When tree crowns begin to touch each other at intermediate stage, diameter growth declines. Tree rings become narrower as competition increases. If the silviculture practices (thinning, pruning, improvement felling)are not carried tree growth remains slow to maturity, the tree may even die. If the competing trees and other plants are thinned, the competition for light, space, water and nutrients can be reduced.There is a shift in teak plantation management from government sectors to private farm lands and plantation companies. In turn, this shift led to intensive management of teak plantations and consequent reduction in rotation age of plantation. In

this context, this paper reviews the various silviculture techniques currently being adopted in relation to silviculture of teak and alsoto increase the growth, productivity and quality of timber under monoculture plantations as well as under various agroforestry systems.

Comment [CP2]: The paragraph does not present sources of consultation, please add the authors of the information presented.

Silvicultural characteristics of teak: Teak seedlings are sensitive to frost and drought. It is a strong light-demander, intolerant of suppression and weeds. Seedlings and saplings killed back by fire and frost. It coppices and pollards vigorously, up to about middle age. Teak is a pronounced light demander and does not tolerate suppression at any period of its growth. It is also fairly fire tolerant.

Comment [CP3]: Query source is missing

Climate and soil condition: The tree grows under a wide range of climatic conditions. It grows up to an altitude of 1200m from sea level. Precipitation range of less than 900 mm to more than 2500 mm. The most suitable soil for teak is the deep, well drained alluvium soil having relatively high contents of calcium and phosphorus. pH range of 6.5 to 8.0 but good growth is attained on soils of pH 6.5. Natural teak forests occur on black and red soils developed from the underlying rock*viz*. Sandstone, granite-gneiss and basalt in different parts of India including Madhya Pradesh, Maharashtra, Tamil Nadu, Karnataka and Kerala. Base-rich soils with high organic carbon and exchangeable calcium are highly suitable for teak. Recycling of nutrients specifically exchangeable calcium and magnesium is common in teak forests(Choudhari and Prasad,2018). Direct correlation between teak growth and soil factors such as pH, exchangeable calcium, magnesium and phosphorus, whereas no significant correlation was found between organic matter content and teak growth (Bhatia, 1954).

Comment [CP4]: Find a more current reference source

Plantation management practices / Silvicultural techniques

Comment [CP5]: The topic does not have sources of consultation, please add the sources from where the information was obtained.

Site preparation:As teak is a long rotation crop land preparation is the most important aspect. Well drained alluvial soil is the most suitable soil for teak growth. The site should be prepared to ensure that planting can proceed without delay. Site preparation involves removal of competing vegetation from the site,create conditions that will enable the soil to catch and absorb rainfall as possible and reduce the surface runoff to increase the moisture in the soil.Provide good rooting conditions for the planting, including a sufficient volume of rootable soil. Eliminate the hardpans and create conditions where danger from fire and pests is minimized.Site preparation is directed toward giving the seedlings a good start with rapid early growth.

Spacing: Spacing is defined as the distance between the plants put out in a planation or standing crop.Spacing is one of the silvicultural techniques for optimizing their growth. Fastgrowing tree species, *i.e*. selected clonal teak, will produce high productivity, but they require the most suitable plant types and spacing arrangements. The spacing is an important aspect of increasing forest yield, forest productivity and forest economic value.

Pitting:Before going for pitting make sure that the land should be free from weeds. After proper tillage operations, pitting is done at 1.5×1.5 ft. While carrying out the pitting operations the surface soil and underground soil are kept in separate side. The objective of creating planting pits is to aerate and loosen the soil in which the plants can grow rapidly.

Planting:The planting season generally coincides with the rainy season. Planting can also be initiated when the soil is wet to a specified depth (approximately 20 cm).Selection of good quality seedlings is the main factor to be considered for successful planting operations. Basically seedlings with 1.5 to 2 ft. height are recommended for planting. Selection of quality seedlings depends on straight stem, branching pattern and prominent root zone.

Irrigation: Drip irrigation system is the most suitable method for teak plantation. Optimum utilization of water is possible in drip irrigation system. Furrow method of irrigation is also been followed in areas where the water availability is high. It will take around 15-20 days for teak seedlings to survive under optimum climatic conditions.

Fertilizer Management:The recommended dose per tree is 50 g of NPK in the first year, 100 g in the second year and 150 g in the third year. Apply manure or compost at a dose of 10 kg per planting hole before planting the tree.Generally for teak plantation NPK ratio recommended is about 150:100:100kg NPK/ha. After initial planting 10g of DAP can be applied in 3 months interval which enhances the growth. After planting Nitrogen in the form of urea at 50g in 6 months interval and Phosphorous in the form of SSP (Single Super Phosphate) at 30g in 6 months interval is recommended for teak.

Weeding:weeding may be defined as atendingoperation done in seedling stage, nursery or in a forest crop that involves the removal or cutting back of all the weeds. Teak is a light-demanding species but under poor light conditions its growth and development are reduced sharply. Weeding must be done in plantations during the rains and stopped by the end of September. Intensive weeding is recommended for teak during the early establishment of the plantation.

Pruning:Pruning is one of the important silvicultural practices adopted to improve the productivity of the teak planation. Pruning involves removal of live or dead branches or multiple leaders from standing trees for the improvement of the trees or its timber.Trees with the height of about 7 ft. to 10 ft. with more prolific side branches need to be pruned in order to facilitate the growth.The removal of branches which increases clear bole height and reduce knots on the main stem. By removing unnecessary branches or twigs, the tree growth will concentrate around the main stem and its canopy.

Thinning:A felling made in an immature stand for the purpose of improving growth and form of the trees. The thinning can be done on the basis of the basis of leading trees in the area, productive capacity of the site and optimum trees to be retained after thinning. Depending on site

quality and the size of initial spacing the first and second thinning is conducted at 5 and 10 years respectively. The removal of stressed, unhealthy and slow-growing trees will encourage better growth for the good quality trees that remain. Thinning helps maximise tree growth, prevent the spread of disease and distribute trees more evenly.

Pest and disease management:Teak is naturally resistant to various biotic stress components due to the presence of tectoquinone and other extractive contents. Teak is a long rotation crop provides sufficient time for pests and diseases to feast upon teak at various growth stages starting from nursery to timber mills which leads to a downturn in timber production. The biotic factors such as insect pests, fungal and bacterial infections, are currently limiting teak wood production. Identification of plus trees with genetic resistance, molecular characterization and monitoring of pests and diseases on teak harnessing the recent developments in plant protection, along with the research on development of the package of practices for teak nurseries and plantation management, will only sustain teak production in near future.

Improved planting stock:Improved planting stock for teak trees can be produced using clonal seed orchards, tissue culture. Plantations established using seedling and shoot cuttings help to improve forest productivity.

Short rotation crop (Tissue culture teak): Shorter rotation periods are being increasingly practised worldwide to meet the growing demands and to support teak growers. Teak clonal forestry has demonstrated its efficiency for short rotation plantations worldwide. Currently, most teak plantations in tropical and subtropical countries are raised from tissue culture derived planting stock.

Growth and productivity of teak under different silviculturalmanagement practices

Teak (*Tectonagrandis*L.f.) is one of the most important tropical hardwood tree species in the world. Since the late 20^{th} and into the early 21^{st} century, the production in the global wood market of premium teak wood from natural forests has been declining because of deforestation of natural teak forests, land-use changes, over exploitation and unsustainable forest management (Pandey and Brown, 2000).In Asian Pacific region, teak has been managed under longer rotations of 35–80 years with annual productivity in the range of 5–20 m^3 ha^{-1} $year^{-1}$, while teak plantations in Africa are generally harvested at shorter rotations of around 20 years with lower productivity around 4–13 m^3 ha^{-1} $year^{-1}$ (Bhat and Hwan, 2004).

Víquez and Perez(2005)reported that under an intensive pruning regime, a teak tree at rotation (20 years) may yield over 40 per cent of knot-free volume (over 60% of the merchantable tree volume). Ratios of height to diameter of stem and crown diameter to length increased with pruning intensity because of the distinct increase in tree height. The wound occlusion rate and the

proportion of complete occlusion were relatively higher when pruning intensity was 55 per cent in the vigorous growth period. Pruning intensity strongly affected teak stem form (Zhang *et al*. 2022). Numerous studies have reported that the effects of pruning on diameter growth of trees are insignificant and had positive correlation with growth of tree(Roshetko*et al*. 2013, Budiadi*et al*. 2017).

The teak plantations from shoot cuttings would increase growth and forest productivity. Widiyatno*et al*. (2024) observed thatdiameter, heightandclear boleheightvalues were (28.4%), (46.8%)and (49.1%) higher, respectively, in teak plantations from shoot cuttings than from seedling. Rahmawati *et al*. (2022) studied that how spacing had effect on growth and development of 8 year old clonal teak planation. The spacing had a significant effect on DBH, tree height, bole height, carbon sequestration and volume of teak clones aged 8 years and indicated that wide spacing was beneficial in terms of teak growth. The diameter increased with the wider spacing due to a lower stand density (Vigulu*et al*. 2019).

Comment [CP6]: Separate the words underlined in red

Increased space between plants helps crown and root development due to reduced competition (Zahabu*et al*., 2015). Competition between trees is related to stand density, where the denser the stand, the more competition between trees will increase.Wider plant spacing and higher thinning intensity can increase the diameter class, thus increasing the selling price of the timber.Pachas*et al*. (2019) reported that small woodlots established at high initial stocking rates with little management practices individual tree diameter, height and volume was maximisedat the lowest initial stocking.

Shukla and Viswanath (2014) reported that Mean Annual Increment (MAI) of 0.020, 0.006 and 0.016 m^3 $tree^{-1}$ $year^{-1}$ was recorded in Line unmanaged plantation (Lum), Boundary unmanaged plantation (Bum) and Boundary intensively managed plantation (Bim) respectively. The total biomass production recorded in intensively managed block plantation (Bim) (217 kg $tree^{-1}$) was higher than the other two types. Silvicultural thinning is a way to stimulate plant conditions and increase the growth parameters of tree (Djati*et al*., 2014 and Sevise*et al*., 2017). The diameter growth showed higher growth at larger spacing and higher thinning intensity. The tree height increased with the thinning intensity. The Current Annual Diameter Increment (CADI) after two years of thinning increased by 14-42 per cent at 25 per cent thinning intensity and increased by about 35-48 per centat 50 per cent thinning intensity compared to no thinning at each spacing (Rahmawati*et al*. 2024);thus thinning plays an essential role in optimizing teak growth. The 3.0 m pruning treatment produced trees with a better DBH/total height relationship compared to 4 m and 5 meter pruning of tree (Víquez and Perez, 2005).

Wood quality of teak under different silvicultural management practices

Teak is the most valued species for structural and non-structural applications and has always commanded a high price in retail market. The current domestic resources of teakwood are not able to meet the huge market demand. Non availability of quality planting material and unscientific management practices have greatly hampered production of quality teak wood (Ball *et al*. 2000).Because of its aesthetic value and superior wood qualities, teak plantations attract larger interest among the general public than any other tropical hardwoods (Shukla and Viswanath, 2014). Teak has also been grown successfully in farmers fields in semi-arid conditions under various planting densities, spacing and with intercrops. Wood quality parameters of teak (anatomical, physical and strength properties) are generally expected to attain the mechanical maturity at the age of rotation.Specific gravity or wood density can be an important variable in determining wood quality parameters (Bhat*et al*. 2001).Several works have been reviewed to check the effect of different silvicultural practices on wood quality of teak.The stress wave velocityof shoot cuttings planting stock plantation was 3.6per cent higher than from seedling (Widiyatno, 2024).

Short rotation teak was less dense and less durable due to lower heartwood and extractive contents. The short rotation teak was not particularly different in swelling, MOE and MOR and Brinell hardness compared to long rotation teak. Lower wood density and durability of the short rotation compared to the long rotation teak will restrict its utilization to some extent for both indoor and outdoor applications. Careful attention should be given to the use of short rotation teak in some wood-processing technologies (Rizanti*et al*. 2018). Highest percentage of tectoquinone in the acetone extract of long rotation teak is responsible of teak natural durability (Lukmandaru and Ogiyama, 2005).This difference in tectoquinone content may explain the lower decay durability of short rotation teak compared to long rotation one.Martawijaya*et al*. (2005) reported that density of long rotation teak ranges from 620 to 750 kg/m^3 with an average of 670 kg/m^3. (Rizanti*et al*. 2018) reported long rotation teak density was 664 kg/m^3, while for short rotation teak was 472 kg/m^3. Darmawan*et al*. (2015) reported the average density values of short rotation and long rotation teak woods is 486 and 670 kg/m^3 respectively.

Rahmawati*et al*. (2022) reported that spacing had no such significanteffectonthe physical and mechanical properties of wood in 8 year old clonal teak planation. The 6 m × 2 m spacing had high values of bending strength (MOR), compressive strength parallel (MCS), which was 67.14 N/mm^2, 33.75 N/mm^2 respectively. The highest percentage of heartwood at a spacing of 6 m × 2 m (40.95%) did not differ much from 10 m × 2 m (40.86%);whereas, spacing of 10 m x 2 m had the highest wood density (0.48 g/cm^3). The heartwood is a naturally durable part of the wood that is not susceptible to organic destruction (Anish*et al*. 2015) and it is an important factor in determining teak wood quality.

Comment [CP7]: Separate the word

Wood quality of teak plantations can be improved through prudent silvicultural management techniques like thinning and pruning. If Silviculture management practices are carried out judiciously at the appropriate time, it would improve the quality of wood by producing knot free timber and bends, less taper and more heartwood.Gama Widya*et al*. (2023) examined that different thinning intensities had no significant impact on wood basic density alteration, while pruning intensities affect the differences between radial and volumetric shrinkage. The thinning and pruning regimes can enhance the mechanical properties without having a serious alteration in the physical properties of clonal teak wood. Heavy and moderate thinning intensities on teak in India and Myanmar did not significantly change the strength properties (Kadambi, 1972).Víquez and Perez (2005) reported that heartwood volume was found to be greater in the 3.0 m pruning than 4.0 m and 5.0 m pruning. The 3.0 m pruning presented 142per cent more heartwood volume than 4.0 m and 5.0 m pruning and 35 per cent more than the control.

CONCLUSION

Teak (*Tectona grandis* L. f.) is one of the most important tropical hardwood tree species in world and popularly known as "King of timbers''. It is the most valued species for structural and non-structural applications and has commanded a premium price in global market. With diminishing supply of timber from the natural forests, attention has now been shifted considerably towards fast grown plantation species to meet the timber deficit. Silviculture techniques are a tool for commercial tree farming to attain the maximum growth and productivity. Stand management practices such as plant spacing, thinning and pruning influence diameter, height growth and commercial volume of timber. In order to obtain knot-free timber of teak, regular pruning should be carried. The implementation of thinning and pruning regimes in the clonal teak plantation as part of intensive silvicultural techniques helps to improve the growth and productivity of teak plantation. Lower wood density and durability of the short rotation teak compared to the long rotation teak will restrict its utilization to some extent for both indoor and outdoor applications. Hence, with the adoption of silvicultural practices specific to the species, the prodcutivity can be enhanced without comprimising the quality of the produce.

REFERENCES

Anish M C, Anoop E V, Vishnu R, Sreejith B, Jijeesh C M, 2015, Effect of growth rate on wood quality of teak (*Tectona grandis* L. f.): a comparative study of teak grown under differing site quality conditions. *Journal of Indian Academy Wood Science*, 12(1): 81-88.

Anonymous, 2000, Global Forest Resources Assessment, Food and Agriculture Organization, 140: 23-38

Anonymous, 2022, The Observatory of Economic Complexity report,online data visualization and distribution platform.

Anonymous, 2024, Data market bridge report,Global teak wood packaging market size, share and trends analysis report.

Ball J B, Pandey D, Hirai S, 2000, Global overview of teak plantations. In: Regional seminar on site, technology and productivity of teak plantations. Chiang Mai, Thailand, 26-29 January 1999. p. 11-34.

Bhat K M, Indira E P,1997, Effect of faster growth on timber quality of teak. K.F.R.I. Research Report, pp. 60.

Bhat K M, Priya P B, Rugmini P, 2001, Characterisation of juvenile wood in teak. *Wood Science and Technology*, 34: 517-532.

Bhat KM, Hwan OM, 2004, Teak growers unite. Tropical Forest Update 14(1):3-5.

Bhatia K K, 1954, Factors in the distribution of teak and a study of teak forests in Madhya Pradesh. *Ph.D*. Thesis, University of Saugar,Madhya Pradesh.

Budiadi, Widiyatno and Ishii H, 2017, Response of a clonal teak plantation to thinning and pruning in Java, Indonesia.*Journal of Tropical Forest Science*, 29: 44-53.

Chelliah, Buvaneswaran, Anurag Ravi and NagarnambiMuthurasu, 2021, Modern silvicultural practices and productivity of teak. *The Teak Genome* : 27-44.

Choudhari P and Prasad J, 2018, Teak supporting soils of India: a review. *Open Access Journal of Science*, 2(1):198-200.

Darmawan W, Nandika D, Sari R K, Sitompul A, Rahayu I and Gardner D,2015, Juvenile and mature wood characteristics of short and long rotation teak in Java. *Iawa Journal* 36: 429-443.

Djati I D, Takatoshi T, Mitsunori K and Fumio T,2014, Sapwood of young teak from thinning as potential material for making products: case studies sapwood of young teak from teak plantation in Java, Indonesia. Bulletin of JSSD, 61: 77-86

Gama Widya, Hidayati F, Widiyatno W and Mohammad N I, 2023, Wood physical and mechanical properties of clonal teak (*Tectonagrandis*) stands under different thinning and pruning intensity levels planted in Java, Indonesia. *Journal of the Korean Wood Science and Technology*, 51(2): 109-132.

Haridas S M, 2017, Geographical Indications status for Nilambur Teak (*Tectonagrandis*Lf). *M. Sc. (For.) Thesis*, Kerala Agriculture University, Kerala, India.

Kadambi K, 1972, Silviculture and management of teak, Forestry Bulletin No. 24.

Lukmandaru G, Ogiyama K, 2005, Bioactive compounds from ethyl acetate extract of teakwood (*Tectonagrandis*L.f.) Wood Biomass 6: 413-416.

Martawijaya A, Kartasujana I, Kadir K and Prawira S A, 2005, Atlas kayu Indonesia, Jilid I (Indonesian Wood Atlas, Volume I). DepartementKehutanan–BadangPenelitiandanPengembanganKehutanan: Bogor, Indonesia.

Pachas A N A, Sakanphet S, Soukkhy O, Lao M, Savathvong S, Newby J C, Souliyasack B, Keoboualapha B and Dieters M J, 2019, Initial spacing of teak (*Tectonagrandis*) in northern Lao PDR: Impacts on the growth of teak and companion crops. *Forest Ecology and Management*, 435: 77-88.

Pandey D, Brown C, 2000, Teak: a global overview. Unasylva, 51(201): 3-13.

Rahmawati R B, Hardiwinoto S Widiyatno, Budiadi and Wibowo A, 2024, Productivity of clonal teak plantation under different spacing and thinning intensity in Java Monsoon Forest. Paper presented In *IOP Conference Series: Earth and Environmental Science*, 1299(1): 012004.

Rahmawati R B, Widiyatno W, Hardiwinoto S, Budiadi B, Nugroho W D, Wibowo A and Rodiana D, 2022, Effect of spacing on growth, carbon sequestration and wood quality of 8-year-old clonal teak plantation for sustainable forest teak management in Java Monsoon Forest, Indonesia. *Biodiversitas Journal of Biological Diversity*, 23(8): 4180-4188.

Rizanti D E, Darmawan W, George B, Merlin A, Dumarcay S, Chapuis H, Gelhaye E, Kartika S R and Syafii W, 2018, Comparison of teak wood properties according to forest management short versus long rotation. *Annals of Forest Science*, 75(5): 1-12.

Roshetko J M, Rohadi D, Perdana A, 2013, Agroforestry systems for livelihood enhancement, industrial timber production and environmental rehabilitation. *Forests, Trees and Livelihoods*, 22: 241-256.

Seta G W, WidiyatnoHidayati F, Naiem M, 2021, Impact of thinning and pruning on tree growth, stress wave velocity and pilodyn penetration response of clonal teak (*Tectonagrandis*) plantation. *Forest Science and Technology*, 17(2): 57-66.

Seviset S, Thanate P, Udomsak S, Ratthai P, Kananke R and Sittichai C,2017, Mechanical property of 9 years old thinning of teak plantation in Thailand.MATEC Web of Confernce, 95 03004.

Shankar T M V, 2022, Growth and productivity as function of site quality and age in teak plantations of Nilambur, Kerala. *M. Sc. (For.) Thesis*, Kerala Agriculture University, Thrissur, Kerala, India

Shukla S R and Viswanath S, 2014, Comparative study on growth, wood quality and financial returns of teak (*Tectonagrandis*Lf) managed under three different agroforestry practices. *Agroforestry systems*, 88(5): 331-341.

Vigulu V, Blumfield T J, Reverchon F, Hosseini B S and Xu Z, 2019, Growth and yield of 5 years old teak and flueggea in single and mixed species forestry systems in the Solomon Islands. *New Forests*, 50(4): 629-642.

Víquez E and Perez D, 2005, Effect of pruning on tree growth, yield, and wood properties of *Tectonagrandis* plantations in Costa Rica. *Silva Fennica*, 39(3): 381-390.

Widiyatno, Wibowo A, Novitasari D, Seta G W, Prehaten D, Hidayati F, Nugroho W D, Hardiwinoto S, Na'iem M and Tani N, 2024, Effect of improved planting stock on tree growth, wood properties and soil fertility of teak plantations 10 years after planting. *Forest Science and Technology*, 20(1): 8-15.

Zahabu E, Tumaini R, ShabaniA, Omari C, Iddi S and Rogers E, 2015, Effect of spacing regimes on growth, yield and wood properties of *Tectonagrandis* at Longuza forest plantation, *Tanzania International Journal of Forest Research*, 1-6.

Zhang Q Q, Zhou Z Z, Huang G H, Zhao W W, Liu G F and Wang X B, 2022, Effects of pruning intensity and season on wound occlusion and stem form of teak (*Tectonagrandis*) in China. *Journal of Tropical Forest Science*, 34(4): 439-449.

Table 1: Wood properties of teak under different silvicultural management practices

Comment [CP8]: Tables are not mentioned in the document.

Silvicutural practices	Age of the plantation (yr)	Wood properties	Values	Reference
Spacing (6 × 2 m)	8.0	Per cent heartwood	40.95	Rahmawati*et al.*(2022)
		MOE (N/mm^2)	8430.19	
		MOR (N/mm^2)	67.14	
		MCS (N/mm^2)	33.75	
Pruning at 3m of height	6.1	Heartwood volume m^3ha^{-1}	45.4	Viquez and Perez (2005)
Intensively managed block plantation	12	Specific gravity	0.559	Shukla and Viswanath (2013)
		Volumetric shrinkage (%)	9.14	
		Modulus of rupture - (MPa)	82.10	
		Modulus of elasticity- (GPa)	8.19	
		Fibre stress at limit of proportionality- FS at LP (MPa)	54.99	

Table 2: Different extractive content of short (10 years) and long rotation (40 years) teak

Extractives (%)	Long rotation teak	Short rotation teak
Dichloromethane extractive content	2.8 ± 0.10	0.5 ± 0.06
Acetone extractive content	1.1 ± 0.28	0.3 ± 0.05
Toluene/ethanol (2/1) extractive content	1.6 ± 0.15	0.4 ± 0.06
Water extractive content	2.5 ± 0.45	2.5 ± 0.48
Total extractive content	8.0 ± 1.55	3.7 ± 0.85
Holo-cellulose	68.53 ± 0.63	67.50 ± 1.53
Cellulose	49.18 ± 0.60	48.80 ± 1.19
Hemi-cellulose	19.35 ± 0.92	18.70 ± 1.72
Lignin	32.19 ± 0.76	35.53 ± 0.78

(Rizanti*et al*. 2018)

Table 3: Comparison between wood properties of short (10 years) and long rotation (40 year) teak

Wood properties	Long rotation teak	Short rotation teak
Basic density (kg/m^3)	664 ± 3	472 ± 2.65
Volumetric swelling (%)	7.2 ± 0.7	8.4 ± 0.5
Vessel frequency ($vessels/mm^2$)	4.20	5.50
MOE (N/mm^2)	12,861.8 ± 40.9	9929.3 ± 687.0
MOR (N/mm^2)	118.9 ± 1.9	97.4 ± 12.6
Brinell hardness (N/mm^2)	35.2 ± 0.6	27.9 ± 0.3

(Rizanti*et al*. 2018)