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PRODUCTIVITY OF SELECTED TEAK CLONES IN A CLONAL SEED ORCHARD

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ABSTRACT

The present investigation was carried out in a 31 to 32 years old clonal teak plantation located at the Silvicultural Research Station-Koshala in Angul district of Odisha, India to assess the productivity of selected teak clones. At 31 years of age, the DBH and height of the clones were found in the range of 19.22 to 26.60 cm and 15.23 to 19.45 m, respectively and the stem volume at 32 years ranged from 55.26 to 185.08 m^3/ha of the plantation with a MAI range of 1.73 to 5.78 m^3/ha/year and a CAI range of 12.99 to 28.99 m^3/ha. Clone ORPUB9 produced both highest number of flowers of 5031 and highest number of fruits while ORPUB10 recorded the lowest number of fruits per tree in a year. Clone ORPUB2 recorded highest fruit weight from a range of 11.45-44.70g. The percentage of viable fruits was maximum under ORPUB13 at 70% from a range of 30-70%.

INTRODUCTION

Tectona grandis Linn. f. (Teak), a member of the family Verbenaceae, order Laminales (Troup, 1921), is an important timber species because of its unique wood properties and the value of its wood (Anon., 1956). At global level distribution of teak plantation naturally occurs in most of the tropical and subtropical parts of the world. It is native to south and Southeast Asia, mainly India, Burma, Thailand, Laos, Cambodia, Vietnam and Indonesia, but is naturalized and cultivated in many countries in Africa and the Caribbean. Teak has been introduced as a plantation species in as many as 36 tropical countries across tropical Asia, Africa and South and Central America (Ball *et al.,* 2000).

Teak is the world's most cultivated high-grade tropical hardwood, covering approximately 6.0 million hectares worldwide (Bhat and Hwan Ok Ma 2004). The plantations in Asia Pacific region (5.3 million hectares) have been managed under 35 to 80-year rotations, yielding annual productivity of 5 to 20 m^3 ha^{-1} $year^{-1}$, while teak plantations in Africa (310,000 hectares) are harvested at shorter rotations of 20 years, yielding between 4 and 13 m^3 ha^{-1} $year^{-1}$ (Bhat and Hwan Ok Ma 2004). Central and South American teak plantations (205,000 ha) are being managed under similar short rotation scenarios of 20-25 years, however they have shown higher yields of up to 40 m^3 ha^{-1} $year^{-1}$ (average of 20-25 m^3 ha^{-1} $year^{-1}$ on medium and high quality sites) (Prez, 2005). In India, the annual national target for teak plantation establishment by different states is 50, 000 hectares. However, the productivity of teak is very low in most of the plantations because of poor genetic makeup of the planting stock (Bhat and Hwan Ok Ma 2004). According to Pandey and Brown (2000) at 50-year rotation age, the MAI for best, average and poor sites in India are 10.0, 5.8 and 2.7 m^3 ha^{-1} $year^{-1}$, respectively.

Teak has been grown under plantation conditions for 150 years (Ball *et al.,* 2000). In the recent years, its high value as timber of excellent appearance and mechanical resistance, and the appearance of strong markets for teak products which parallels an increasingly declining stock of natural stands, have attracted particular attention to the potential of teak plantations as a high return investment possibility (Ball *et al.*, 2000). In this context, it is necessary to select teak clones with characters of higher productivity and propagate their planting materials in large scale for mass plantations. Keeping this in view the present study was carried out to assess the productivity of some clones grown in a clonal seed orchard in Odisha.

MATERIALS AND METHODS

The study was conducted at Silvicultural Research Station, Koshala, Angul of Odisha, India during January 2013 to June 2014. The experimental plot was a clonal seed orchard of Teak comprising of 15 clones derived from Purunakote and Barbara provenances of Odisha. The experiment was laid out in Randomized Block Design (RBD) with two replications. There were 15 numbers of clones of Teak (*Tectona grandis* L.) as treatments. The clones were planted at a spacing of 8.0 m × 5.6 m in the year 1982. There were 390 trees in the experiment. The experiment was evaluated during 2013-14 when the clonal plants attained the age of 31-32 year old. The study area falls under tropical wet and dry climate. It has a warm and moist climate characterized by humid summer and mild winter. The average annual rainfall of the area is 1421 mm. The soil is loamy sand to sandy loamy in texture and slightly acidic in nature.

The observations were recorded on DBH, height, number of flowers per inflorescence, number of fruits per tree, 100 fruit weight, viability of fruits, volume of stem, mean annual increment (MAI) of stem volume and current annual increment (CAI) of stem volume. The DBH was measured with the help of caliper in two directions following the standard procedure. The height of trees was measured by using Ravi Altimeter (Palanisamy *et al.*, 2009). The number of flowers per inflorescence and number of fruits per tree were counted by taking photographs with high resolution camera. The 100 fruit weight was determined by weighing air dried fruits in digital balance in the laboratory. The viability per cent of fruits was determined through tetrazolium chloride test (TZ test) (Jatt *et al.,* 2007). The volume of stem per tree was calculated by using the formula suggested by Forest Survey of India (FSI, 1996; Salunkhe *et al.,* 2016) for Odisha *i.e.*

VUB (m^3) = $-0.0645 + 0.2322D^2H$

Where,

VUB = Volume under bark

D = DBH over bark

H = Height of the tree

The volume of stem per hectare was calculated by multiplying the average volume of stem per tree with plant population per ha, and was expressed in m^3/ha.

The MAI of stem volume per hectare was estimated by dividing the total volume per hectare by the age of trees, and was expressed in m^3/ha/year. The CAI of stem volume was determined from the difference in volume calculated in January, 2013 from that of January, 2014. It was expressed in m^3/ha.

The data on various observations were analyzed as per the procedure described for RBD. The standard error of means *i.e.* $SE_{(m)}$ was calculated at 5% level of significance and so also the critical difference (CD) (Palanisamy *et al.*, 2009).

SE_m (±) = “EMS/R

Where,

EMS = Error Mean Square

R = Number of replication

RESULTS AND DISCUSSION

The DBH of trees differed significantly among different clones at both the years of study (Table 1) with a range of 19.22 to 26.60 cm at the inception year of study (31 years old) and 20.61 to 28.01 cm at the subsequent year of study. Among the clones, clone ORPUB18 reported the highest DBH in both the years of study whereas clone ORPUB13 exhibited the minimum DBH. At 32 years of age the order of diameter growth was recorded as ORPUB18 > ORPUB20 > ORPUB10 > ORPUB21 > ORPUB1 > ORANP1 > ORPUB8 > ORANP2 > ORPUB11 > ORPUB9 > ORPUB2 > ORPUB12 > ORPUB5 > ORPUB3 > ORPUB13. The performance of clone ORPUB18 was statistically similar to that of ORPUB1, ORPUB10, ORPUB20 and ORPUB21. Similarly, the value of ORPUB13 was statistically similar with that of ORPUB3, ORPUB5 and ORPUB12, which are in line with the findings of Saxena *et al.* (1971) and Kharche (1974). As per the findings of Palanisamy *et al.* (2009) on some selected superior teak clones of 51-64 years old, the range of girth at breast height (gbh) was 151–220 cm (48-70cm DBH). The variation in diameter growth may be ascribed to difference in genetic characteristics of different clones as reported by Gera *et al.* (2001). The significantly higher growth of DBH in ORPUB18 may be due to better genetic makeup of the clone governing the lateral growth of the stem and the lowest growth of ORPUB13 may be due to the poor genetic character of the clones that influence the expansion of secondary meristem.

The data in Table 1 reveal a significant variation in the total height of trees of different clones at the age of 31 years and

Table 1: Diameter and height growth of different Teak clones

Treatment/ Clone	DBH (cm)		Total Height (m)	
	31 year old	32 year old	31 year old	32 year old
T_1:ORPUB1	24.32	25.84	17.31	17.33
T_2: ORPUB2	22.50	24.34	15.72	15.74
T_3: ORPUB3	20.45	21.73	17.13	17.14
T_4: ORPUB5	20.67	22.01	16.86	16.89
T_5: ORPUB8	22.87	24.51	18.00	18.03
T_6: ORPUB9	22.48	24.40	17.21	17.25
T_7: ORPUB10	25.01	26.79	18.55	18.56
T_8: ORPUB11	22.54	24.42	18.01	18.02
T_9: ORPUB12	20.87	22.24	17.33	17.35
T_{10}: ORPUB13	19.22	20.61	15.23	15.31
T_{11}: ORPUB18	26.60	28.01	19.45	19.46
T_{12}: ORPUB20	24.88	26.80	18.42	18.45
T_{13}: ORPUB21	24.53	26.58	18.85	18.87
T_{14}: ORANP1	23.90	25.70	18.68	18.69
T_{15}: ORANP2	23.07	24.47	17.20	17.21
$SE_{(m)}$ ±	0.83	0.74	0.42	0.42
C.D. $_{(0.5)}$	2.53	2.26	1.28	1.27

Table 2: Flower and fruit production and fruit viability of different Teak clones (32 year old stand)

Treatment/ Clone	No of flowers/ inflorescence	No of fruits/ tree	100 fruit weight (g)	Fruit viability (%)
T_1:ORPUB1	4658	459	37.65	65.00
T_2: ORPUB2	4460	507	44.70	45.00
T_3: ORPUB3	3789	373	42.66	60.00
T_4: ORPUB5	4459	533	17.72	50.00
T_5: ORPUB8	4065	474	41.98	45.00
T_6: ORPUB9	5031	666	35.76	30.00
T_7: ORPUB10	3522	259	31.26	40.00
T_8: ORPUB11	3975	455	21.63	55.00
T_9: ORPUB12	4841	629	17.83	35.00
T_{10}: ORPUB13	4257	560	41.33	70.00
T_{11}: ORPUB18	4035	422	39.72	40.00
T_{12}: ORPUB20	3854	439	38.97	55.00
T_{13}: ORPUB21	4303	559	11.45	50.00
T_{14}: ORANP1	4068	504	31.45	60.00
T_{15}: ORANP2	4186	602	27.35	45.00
$SE_{(m)}$ ±	103	11	0.57	3.52
C.D. $_{(0.5)}$	313	36	1.74	10.67

Table 3: Production of stem volume of different Teak clones

Treatment/ Clone	Stem volume (m^3/ha)		MAI of stem volume (m^3/ha)		CAI_{31-32} of stem volume (m^3/ha)
	31 year old	32 year old	31 year old	32 year old	
T_1:ORPUB1	110.89	130.70	3.58	4.08	19.81
T_2: ORPUB2	76.86	97.07	2.48	3.03	20.22
T_3: ORPUB3	65.17	78.91	2.10	2.47	13.74
T_4: ORPUB5	65.58	80.01	2.12	2.50	14.42
T_5: ORPUB8	98.35	119.31	3.17	3.73	20.97
T_6: ORPUB9	88.34	111.50	2.85	3.48	23.16
T_7: ORPUB10	130.89	156.25	4.22	4.88	25.36
T_8: ORPUB11	94.42	118.00	3.05	3.69	23.58
T_9: ORPUB12	71.61	87.08	2.31	2.72	15.47
T_{10}: ORPUB13	42.27	55.26	1.36	1.73	12.99
T_{11}: ORPUB18	162.67	185.08	5.25	5.78	22.40
T_{12}: ORPUB20	127.66	155.03	4.12	4.84	27.37
T_{13}: ORPUB21	127.31	156.31	4.11	4.88	28.99
T_{14}: ORANP1	116.89	141.87	3.77	4.43	24.97
T_{15}: ORANP2	95.81	112.56	3.09	3.52	16.75
$SE_{(m)}$ ±	5.27	5.28	1.62	1.62	0.78
C.D. $_{(0.5)}$	16.34	16.36	4.93	4.94	2.39

also 32 years of age. The range of variation was observed to be 15.23 to 19.45 m and 15.31 to 19.46 m at two different years, respectively. At the age of 32 years the performance of different clones with regard to total height growth was in the order of ORPUB18 > ORPUB21 > ORANP1 > ORPUB10 > ORPUB20 > ORPUB8 > ORPUB11 > ORPUB12 > ORPUB1 > ORPUB9 > ORANP2 > ORPUB3 > ORPUB5 > ORPUB2 > ORPUB13. The performance of ORPUB18, ORPUB10, ORPUB20, ORPUB21 and ORANP1 was statistically similar. Also ORPUB13 and ORPUB2 performed alike. The variation in height growth may be attributed to the genetic character of the different clones. Gera *et al.* (2001) have also reported that height growth in teak is under the genetic control. The range of height growth is in line with the findings of Rao *et al.* (2001), Prez and Kanninar (2005) and Palanisamy *et al.* (2009). Rao *et al.* (2001) particularly reported that the height growth in a 26 year old teak provenances in Andhra Pradesh at the range of 14.33 to 22.33 m. The superiority of ORPUB18 in terms of height growth may be due to the influence of better genetic character contributing more epical growth. On the other hand, the significantly lower height growth in ORPUB13 may be because of poor expansion of epical meristem.

With regards to reproductive biology of clones, the number of flowers per inflorescence was found to be significantly varied among the clones under investigation (Table 2). Clone ORPUB9 produced highest number of flowers of 5031 and ORPUB10 produced lowest number of flowers of 3522. Statistically similarity was observed in the values between ORPUB9 and ORPUB12 as well as between ORPUB3 and ORPUB10. The productivity with regard to flower production per inflorescence was observed in the order of ORPUB9 > ORPUB12 > ORPUB1 > ORPUB2 > ORPUB5 > ORPUB21 > ORPUB13 > ORANP2 > ORANP1 > ORPUB8 > ORPUB18 > ORPUB11 > ORPUB20 > ORPUB3 > ORPUB10. The variation in number of flower production per inflorescence may be ascribed to the variation in genetic characters of the clone that governs flower production. In a study of similar nature, Mohanadas *et al.* (2002) reported a variation of 5000 to 7000 number of flowers per inflorescence in Kerala.

The production of number of fruits per tree differed significantly among various clones (Table 2). It ranged from 259 to 666. ORPUB9 registered highest number of fruits while ORPUB10 recorded the lowest number of fruits. The number of fruits produced per tree was in the order of ORPUB9 > ORPUB12 > ORANP2 > ORPUB13 > ORPUB21 > ORPUB5 > ORPUB2 > ORANP1 > ORPUB8 > ORPUB1 > ORPUB11 > ORPUB20 > ORPUB18 > ORPUB3 > ORPUB10. The variation in number of fruits produced per tree may be due to the genetic makeup of clones influencing number of flower production, number of inflorescence and intensity of cross pollination. The better performance of ORPUB9 may be correlated to the highest number of flower and fruit production per inflorescence in this clones as discussed earlier. Similarly the poor performance of ORPUB10 may be related to its lowest number of flower and fruit production per inflorescence. Verghese *et al*. (2006), however, has reported fruit production at a range of 1031 to 2013 among different clones of teak in two different Clonal Seed Orchards.

The weight of 100 fruits showed a significant variation among the clones (Table 2). It varied from 11.45 to 44.70 g. Clone ORPUB2 recorded highest fruit weight whereas ORPUB21 registered the lowest fruit weight. The variation in fruit weight of different clones may be attributed to the difference in their genetic characters. Chawhaan *et al*.(2003) have also reported significant variation in fruit size and Hanumantha (2000) have reported similar findings. However, Hardjowasono (1931) have reported higher fruit weight of 56.2 to 63.1 g per 100 fruits.

The fruit viability differed significantly among various clones (Table 2). The maximum fruit viability was recorded to be 70% in ORPUB13, closely followed by clones like ORPUB1, ORPUB3 and ORANP1 respectively. The minimum viability of 30% was observed in ORPUB9. The range of fruit viability is similar to the findings of Shivakumar *et al*. (2002).The variation in fruit viability may be ascribed to the genetic characters of different clones.

The stem volume was significantly different among the various clones at the age of 31 years as well as 32 years (Table 3), ranging from 42.27 to 162.67 and 55.26 to 185.08 m^3/ ha, respectively. Clone ORPUB18 exhibited highest stem volume which was statistically at par with clones like ORPUB10, ORPUB20 and ORPUB21. The lowest stem volume was produced by ORPUB13 which was statistically similar to the values obtained in clones like ORPUB3, ORPUB5 and ORPUB12. At 32 years of age, the performance of stem volume production was in the order of ORPUB18 > ORPUB21 > ORPUB10 > ORPUB20 > ORANP1 > ORPUB1 > ORPUB8 > ORPUB11 > ORANP2 > ORPUB9 > ORPUB2 > ORPUB12 > ORPUB5 > ORPUB3 > ORPUB13. The higher accumulation of stem volume in ORPUB18 closely followed by ORPUB10, ORPUB20 and ORPUB21 may be attributed for the better genetic characters of these clones governing epical and lateral growth of the stem. These clones have witnessed significantly higher DBH and height growth of such clones (Table 1). The significantly lower volume produced by clone ORPUB13 closely followed by ORPUB3, ORPUB5 and ORPUB12 may be because of the poor genetic characters in terms of diameter and height growth. These clones have exhibited poor diameter and height growth as mentioned earlier in Table 1. The range of volume production is in line with the report published by Saxena *et al*. (1971) and Kharche (1974).

A substantial variation in MAI was observed among the clones at both the years of investigation (Table 3), which occurred within the range of 1.36 to 5.25 m^3/ha/year and 1.73 to 5.78 m^3/ha/year at 31 and 32 years of age respectively. The highest MAI of stem volume in both the years of study was exhibited by ORPUB18 and the lowest value was registered by clone ORPUB13. The performances of ORPUB10, ORPUB18, ORPUB20 and ORPUB21 were at par with each other. Similarly the values of ORPUB3, ORPUB5, ORPUB12 and ORPUB13 were statistically similar. The performance of clones at 32 years of age was in the order of ORPUB18 > ORPUB21 > ORPUB10 > ORPUB20 > ORANP1 > ORPUB1 > ORPUB8 > ORPUB11 > ORANP2 > ORPUB9 > ORPUB2 > ORPUB12 > ORPUB5 > ORPUB3 > ORPUB13. The significant variation in the MAI of different clones may be due to the variation in their genetic characters. The superior performance of ORPUB10, ORPUB18, ORPUB20 and ORPUB21 may be attributed to their genetic makeup over others. The significantly poor performance of ORPUB3, ORPUB5, ORPUB12 and ORPUB13 may be ascribed to their inferior genetic makeup with regard to growth of stem. The quantity of stem volume produced is in line with the volume produced by Rao (1973) and Chundamanil (1998). As per Chundamanil (1998), the mean annual increment (MAI) was 2.854 m3 ha^{-1} $year^{1}$ in a 53 year old teak plantation in Kerala, Similarly, Rao et al. (2002) has reported a MAI of more than 8 m3 /ha/year in the best performing clones in Andhra Pradesh, India.

The CAI of stem volume during the age of 31 to 32 years exhibited significant variation among the clones under investigation (Table 3). It ranged from 12.99 to 28.99 m^3/ha. Clone ORPUB21 occupied the highest position whereas ORPUB13 performed the least. The performance of ORPUB21 was statistically at par with ORPUB1, ORPUB2, ORPUB8, ORPUB9, ORPUB10, ORPUB11, ORPUB18, ORPUB20 and ORANP1. Likewise, the performance of ORPUB13 was statistically similar to ORPUB1, ORPUB2, ORPUB3, ORPUB5, ORPUB8, ORPUB12, ORPUB18 and ORANP2. The order of performance at this stage was recorded as ORPUB21 > ORPUB20 > ORPUB10 > ORANP1 > ORPUB11 > ORPUB9 > ORPUB18 > ORPUB8 > ORPUB2 > ORPUB1 > ORANP2 > ORPUB12 > ORPUB5 > ORPUB3 > ORPUB13. The variation in performance with regard to CAI of stem volume may be due to the genetic characters governing the variation in lateral and epical expansion at this stage. The comparatively better performance of ORPUB21 and others may be due to occurrence of highly active primary and secondary meristem at this stage of growth. On the other hand, the poor performance of ORPUB13 and others may be ascribed to the sluggish growth rate of primary and secondary meristems. The range of values for CAI were in line with the findings of Rao (1973) and Tewari (1999).

The present investigation attributes the variation among the clones to their genetic makeups. Barbara provenance of Teak seems to have superiority in terms of both plant growth and reproductive characters. In view of growing demands for quality planting stock of teak for promoting teak based farm forestry and agroforestry in Odisha, clone ORPUB18 may be used for mass propagation and planting. Further research work may also be carried out to find out the best combiner of good attributes.

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APPLICATION FORM

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