International Journal of Plant & Soil Science

Volume 36, Issue 6, Page 720-732, 2024; Article no.IJPSS.117330
ISSN: 2320-7035

Seed Characteristics and Seedling Quality of Selected Teak Clones in Eastern India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/ijpss/2024/v36i64676

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/117330

Original Research Article

Received: 13/03/2024
Accepted: 17/05/2024
Published: 19/05/2024

ABSTRACT

Teak (*Tectona grandis* L.f.) is one of the important timbers of the world and is honoured as the 'King' of Indian timbers. It is grown in large scale by people in farm forestry and agroforestry programme and also by various agencies. To understand the characteristics of seeds and the quality of seedlings raised from seeds of selected teak clones, an investigation was carried out. Fruits were collected from 25 clones of teak grown at Silviculture Research Station, Koshala, Angul, Odisha (India) and tested at College of Forestry, Odisha University of Agriculture & Technology, Bhubaneswar (India). Experiments were carried out under Completely Randomized Design with 3 replications. Significant variation in fruit characteristics such as fruit length, fruit width, 100 fruit weight, number of seeds per fruit, fruit viability and germination percent was observed. Fruit length

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Cite as: *Bhol, N., Roshan, R., Parida, S., & Dash, A. (2024). Seed Characteristics and Seedling Quality of Selected Teak Clones in Eastern India. International Journal of Plant & Soil Science, 36(6), 720–732. https://doi.org/10.9734/ijpss/2024/v36i64676*

varied from 1.08 to 1.57cm and ORANP-4 produced longest fruit while MHALA-7 had minimum value. Fruit width differed from 1.20 to 2.58cm and the highest width was recorded in ORAN-1 (1.58 cm) and lowest in MHALA- 7. Weight of 100 fruits ranged from 34.28 to 56.64g and ORAN-1 recorded maximum fruit weight which was at par with MHALP-9 (54.23 g) while ORPUB -13 registered the minimum value which statistically similar to MHALA-7. Number of seeds per fruit varied from 3.10 to 4.00. Fruit viability varied from 47.56 to 70.38% and ORAN-4 excelled in viability and remained statistically at par with ORPUB-23, MHALA-9 and ORANR-6. Germination percent of fruit varied from 30.5 to 49.50% and ORANP-4 recorded maximum germination percent, but it was statistically similar to MHALA-9 and ORANR-6. The growth and quality of seedlings raised from the open pollinated seeds of clones also exhibited significant difference. MHALA-9 excelled over others with regard to collar diameter, height, number of leaves, shoot weight, root weight and quality of seedling in 15 month of assessment in nursery. It recorded seedling quality index of 16.41 at the age of 15 month.

Keywords: Teak; clone; seed characteristic; seedling growth; biomass, quality.

1. INTRODUCTION

Teak (*Tectona grandis* L.f.) is a pride tree of the world because of its excellent timber quality. It yields one of the world's most beautiful and steady wood in every respect. It is the best Indian timber in dimensional stability and has very low fibre saturation point and shrinkage. In India, in order to classify and group timbers according to functional properties for specific end uses, suitability indices are derived taking teak as standard for comparison. The suitability coefficients for different properties and uses of other species are also expressed with respect to teak as 100 [1]. This is because teak is the most preferred species for various carpentry and other specific uses from time immemorial and comparison with teak gives an idea to users about the suitability of other species. Teak is honoured as the 'King' of Indian timbers.

Teak is paragon among Indian timbers because of its versatile use, easy workability and consistent resilience. In the Indian Standards, it is a representative species of group B constructional timbers. It is considered second to none for ship construction, excellent for all types of constructions, both in and out of water as well as for luxurious interior fittings and expensive furniture. The wood contains oil which prevents nails from rusting. It is a super group timber for shutters, group I timber for frames and is one of the most preferred timbers for making railway coaches, lorry making, etc. It is recognized as the best timber for the manufacture of furniture and cabinet making in the country because of its moderate weight, appropriate strength, dimensional stability and durability, good wood working and finishing qualities.

Tectona grandis is a large deciduous tree upto 50 m high and more than 100cm dbh; base often fluted, a long straight cylindrical bole upto 2/3rd of the height of the tree and sturdy quadrangular branches. It is grown in tropical and subtropical parts of world. Teak tree is indigenous to peninsulas of India, north-eastern drier part of Java and other islands of Indian Archipelago [2]. The natural habitat of teak is between 10°N and 25°N on the Indian subcontinent and in South East Asia, especially in India, Myanmar, Thailand, Laos, Cambodia, Vietnam and Indonesia [3]. Teak has been planted extensively since the beginning of plantation forestry throughout India both within as well outside its natural distributional range. Besides India, it is now grown throughout the tropics in Burma, Thailand, Laos, Indonesia, Nepal, SriLanka, Bangladesh, Pakistan, Vietnam, Malaysia, Fiji Islands, Cambodia, Cameroon, Zaire, Nigeria, Trinidad, Honduras, Senegal, Puerto Rico, Nicaragua, Brazil, Argentina, Colombia, Venezuela, Costa Rica, El Salvador and many other countries. Teak is a highly priced and one of the favourite trees of people because of its excellent wood. Its seed characteristics and quality of planting material play vital role for deciding productivity. For commercial cultivation many clones have been developed by various agencies. The seed characteristics and seedling quality of selected clones of teak was studied and discussed in this article.

2. MATERIALS AND METHODS

The investigation was carried out on 25 number of *Tectona grandis* (teak) clones grown in the clonal seed orchard at Silvicultural Research Station, Koshala, Angul, Odisha (India). The clonal trees have been raised at 6m x 6m

spacing and are 30 year old. The experimental site is located at 21^0 01'N latitude and $84^0$55'E longitude with an altitude of 204m above mean sea level. The area comes under tropical wet and dry climate. The average annual rainfall is 1421mm. The open pollinated seeds of these clones were collected from 75 trees (3 trees for each clone) and subjected to various tests including seedling performance at College of Forestry, Odisha University of Agriculture & Technology, Bhubaneswar (India) which is 165 km away from plantation site. This testing site is located at $20^0$15'N latitude and $85^0$52'E longitude with an altitude of 25.9m above mean sea level. It has warm and moist climate with humid summer and mild winter. The annual rainfall is 1494mm which is mostly received during monsoon period from mid June to mid October.

The matured fruits were collected from standing trees and their physical parameters and viability were tested in the laboratory. All the tests were laid out under Completely Randomized Design (CRD) with 3 replications. Viability percent was determined by putting the horizontally cut fruits in 0.5 % 2,3,5 - Triphenyl Tetrazolium Chloride solution for 24 hours. To study the growth and quality of seedlings, fruits were given pre-sowing treatment of alternate wetting and drying for three weeks in March (summer) and sown in raised nursery bed on 1st April at a spacing of 10cm x 10cm. After one month of germination, one seedling was allowed per fruit and rests were thinned out. Different growth parameters of seedlings were studied at 3 months interval. For this 10 seedlings per replication per clone were uprooted and measured and averaged. Quality of seedling was determined as per the formula given by Dickson et al. [4] as below:

$$\text{Quality Index (QI)} = \frac{\text{Total Dry weight (g)}}{\frac{\text{Shoot Height (cm)}}{\text{Collar Diameter of shoot (mm)}} + \frac{\text{Shoot dry weight(g)}}{\text{Root Dry weight (g)}}}$$

2.1 Cluster Analysis

The clones were categorized into natural clusters combining selected attributes which positively influence the quality of seedlings using NbClust package of R software [5].

Fig. 1. Location of study site in Odisha (red marked)

3. RESULTS AND DISCUSSION

The results of the investigation are presented in Table 1-6 and discussed with cause and effect relationship, whatever necessary and feasible.

3.1 Seed Characteristics of Teak Clones

The characteristics of open pollinated seeds of different clones with respect to size, weight, number, viability and germinability are presented in Table 1.

3.1.1 Fruit length

There was significant variation in fruit length of different teak clones under study. It varied from 1.08 to 1.57cm. ORANP-4 produced longest fruit while MHALA-7 had minimum value. ORANP-4 remained at par with ORANR-4, ORANR-6, ORPUB-26 and ORAN-1. Similarly MHALA-7 was statistically similar to MHALA-4, MHALA-5, MHALP-7, MHWYK-3, ORANP-3, ORANP-15, ORPUB- 2 and ORPUB-13. The variation in fruit length of different teak clones may be because of difference in the genetic makeup of different clones. Nagarajan et al. [6], Sindhuveerendra et al. [7], Chawaan et al. [8] and Jiteesh and Sudhakara [9], Behera [10], Pradhan [11] and Surendra et al. [12] have reported variation in fruit length.

Fig. 2. Open pollinated seeds of ORANP-1

3.1.2 Fruit width

The fruit width varied remarkably among the clones. It varied from 1.20 to 2.58cm. The highest width was recorded in ORAN-1 (1.58 cm) and lowest in MHALA- 7. The value of ORAN-1 was at par with ORANP-I, ORANP-3, ORANP-4, ORANP-15, ORANR-6, ORPUB-10, ORPUB-23, ORPUB-24, MHALP-8, MHALA-9 and MHALP-9. The fruit width of MHALA-7 was statistically similar to MHALA-5, MHALA- 4, MHALP-7, MHALP-9 and MHEMR-2. The difference in width may be due to variation in genetic character and cross pollination among clones. Variation in width of fruit has been reported by Behera [10] and Pradhan [11], Indira et al. [13], Hanumantha [14], Jiteesh and Sudhakara [9].

Fig. 3. Open pollinated seeds of ORANR-6

3.1.3 Weight of 100 fruits

A significant variation in 100 fruits weight was observed among different clones. It varied from 34.28 to 56.64g. ORAN-1 recorded maximum fruit weight which was at par with MHALP-9 (54.23 g). ORPUB -13 weighed minimum and was similar to MHALA-7, ORANP-1, ORANP-3, ORANR-5 and ORPUB-10. The variation in weight of fruits of different clones may be because of difference in their length and width. The highest weight of ORAN-1 may also be related to its maximum fruit width and relatively higher length of fruit. Chawaan et al. (2003), Behera [10], Pradhan [11], Hardjowasano [15], Sindhuveerendra et al. [7], Sivakumar et al. [16], Nagarajan et al. [6], Hanumantha (2000) and Prabhu et al. [17] have reported similar findings.

3.1.4 Number of seeds per fruit

Different clones exhibited wide variation in number of seeds per fruit. It ranged from 3.10 to 4.00. The clones such as ORAN-1, ORANR-4, ORANR-6, ORPUB-23 and ORPUB-24 carried 4 seeds each and remained at par with MHEMR-2, MHEMR-I, ORANP-I, ORANP-3, ORANP-4, ORANP-15, ORANR-5, ORPUB-10 and ORPUB-26. Minimum number of seeds was recorded in

MHALA-9. The difference in number of seeds per fruit in different teak clones may be primarily due to the genetic character of the particular clone. Hung [18], Thompson [19] and Peco et al. [20] have also observed the variation of seed number in teak.

3.1.5 Viability and germinability of fruit

Different clones exhibited significant difference in viability of fruits (Table 1). It ranged from 47.56 to 70.38%. ORAN-4 excelled in viability and remained statistically at par with ORPUB-23, MHALA-9 and ORANR-6. MHALP-8 occupied the lowest position. However, the performance of MHALP-9, MHEMR-I, ORPUB-26 and MHALA-7 was statistically similar to MHALP-8.

There was wide variation in germination percent among clones. It differed from 30.5 to 49.50%. ORANP-4 registered maximum germination percent. It was similar to MHALA-9 and ORANR-6 statistically. The germination percentage was minimum under ORPUB- 26 which was at par with MHALA-4, MHALA-5, MHALA-7, MHALP-8, MHALP-9. MHEMR-I, MHEMR-2 and MHSLA-2.

The variation of viability and germinability percent in different clones may be ascribed to variation in their genetic characters. The results are in line with the findings of Mahmud and Hossain (2012). Behera [10] has reported high heritability (93.44%) in fruit viability of some teak clones of Odisha (India). Pradhan [11] has observed similar findings in fruit viability of some teak clones. Sivkumar et al. [16] also have reported similar range of fruit viability. Palaniswami et al. [21] have noticed that fruit viability in teak varied from 30 to 50%. Mathew and Vasudeva (2003), Prabhu et al. [17]and Surendra et al. [12] also have reported variation in seed germination of teak.

Table 1. Characteristics of open pollinated fruits of different teak clones

S. No.	Clone ID	Fruit length (cm)	Fruit width	Weight of 100 fruits (g)	Number of seeds per fruit	Viability (%)	Germination (%)
1	MHALA-4	1.16	1.28	40.05	3.50	55.43	33.95
2	MHALA-5	1.18	1.22	40.45	3.56	55.45	33.26
3	MHALA-7	1.08	1.20	36.75	3.12	50.33	32.75
4	MHALA-9	1.34	1.51	46.35	3.10	68.33	48.10
5	MHALP-7	1.14	1.31	47.81	3.60	55.80	35.85
6	MHALP-8	1.38	1.52	48.12	3.70	47.56	32.12
7	MHALP-9	1.32	1.38	54.23	3.31	48.13	31.26
8	MHEMR-1	1.28	1.48	44.25	3.98	49.40	31.56
9	MHEMR-2	1.14	1.22	38.12	3.75	60.66	34.50
10	MHSLA-2	1.15	1.26	39.40	3.62	61.35	31.15
11	MHWYK-3	1.22	1.37	48.21	3.32	58.46	40.58
12	ORAN-1	1.35	1.58	56.64	4.00	51.41	35.78
13	ORANP-1	1.25	1.42	36.64	3.81	52.76	36.63
14	ORANP-3	1.21	1.41	34.46	3.78	64.78	44.25
15	ORANP-4	1.57	1.44	45.08	3.95	70.38	49.50
16	ORANP-15	1.22	1.44	43.14	3.75	57.57	39.16
17	ORANR-4	1.52	1.37	45.45	4.00	61.35	42.50
18	ORANR-5	1.25	1.34	34.44	3.72	60.32	39.35
19	ORANR-6	1.39	1.41	45.66	4.00	67.59	47.54
20	ORPUB-2	1.22	1.34	43.05	3.68	60.38	41.78
21	ORPUB-10	1.28	1.39	35.75	3.89	62.65	40.45
22	ORPUB-13	1.16	1.28	34.28	3.65	61.61	43.50
23	ORPUB-23	1.26	1.44	38.52	4.00	68.45	45.70
24	ORPUB-24	1.23	1.46	45.25	4.00	54.15	36.45
25	ORPUB-26	1.37	1.37	45.57	3.75	48.33	30.50
$SE_{(m)\pm}$		0.08	0.07	1.00	0.10	1.30	1.27
$CD_{(0.05)}$		0.22	0.20	3.12	0.28	3.70	3.59

3.2 Growth and Quality of Seedlings of Teak Clones

The growth performance seedlings raised from open pollinated seeds of different teak clones and their quality are presented in Table 2-6. Growth includes diameter, height and biomass of seedlings. The growth and quality of seedlings at different ages till those are ready for planting out (15 month old) are discussed here.

3.2.1 Collar diameter of seedlings

Different clones exhibited significant variation in collar diameter of seedlings. It ranged from 0.36 to 0.76 cm, 0.67 to 1.20 cm, 0.85 to 132 cm and 0.93 to 1.77 cm at 3, 6, 9 and 15 month after sowing, respectively. The diameter increased with increase of age in all clones. At 15 month after sowing MHALA-9 resulted maximum collar diameter (1.77 cm) among the clones, but was similar to MHEMR-2, ORANP-3 and ORPUB-10. MHALA-7 registered minimum collar diameter of seedling and was at par with MHALP-7, ORANP-4, ORANR-4 and ORANR-5.

The collar diameter of seedlings varied significantly among the clones in every assessment. This may be due to variation in genetic makeup of seeds of clones with regard to lateral growth of seedlings. The relatively higher diameter growth of clones like MHALA-9, MHEMR-2, ORANP-3 and ORPUB-10 may be attributed to their better genetic character over others. Nayak et al. [22], Mahmud and Hossain [23] and Nagarajan et al. [6] have reported similar findings. In all clones the diameter increased progressively from 3 to 15 month because the plants are in juvenile stage.

Table 2. Diameter growth of seedlings from open pollinated seeds of different teak clones

S. No.	Clone ID	Collar diameter (cm)				
		At 3 month after sowing	At 6 month after sowing	At 9 month after sowing	Deciduous phase	At 15 month after sowing
1	MHALA-4	0.56	1.00	1.18	-	1.44
2	MHALA-5	0.36	0.67	0.98	-	1.20
3	MHALA-7	0.60	0.81	0.89	-	0.93
4	MHALA-9	0.73	1.20	1.32	-	1.77
5	MHALP-7	0.54	0.80	0.85	-	0.99
6	MHALP-8	0.55	0.80	0.90	-	1.27
7	MHALP-9	0.40	1.04	1.18	-	1.57
8	MHEMR-1	0.53	0.81	1.12	-	1.40
9	MHEMR-2	0.76	1.14	1.21	-	1.66
10	MHSLA-2	0.57	0.81	0.98	-	1.20
11	MHWYK-3	0.76	1.08	1.21	-	1.60
12	ORAN-1	0.62	0.88	0.98	-	1.45
13	ORANP-1	0.50	0.75	1.12	-	1.27
14	ORANP-3	0.54	1.13	1.21	-	1.67
15	ORANP-4	0.54	0.80	0.86	-	1.08
16	ORANP-15	0.43	0.83	0.89	-	1.07
17	ORANR-4	0.66	0.97	1.11	-	1.40
18	ORANR-5	0.40	0.80	0.85	-	1.04
19	ORANR-6	0.54	0.86	1.12	-	1.37
20	ORPUB-2	0.44	0.76	0.96	-	1.30
21	ORPUB-10	0.69	1.10	1.18	-	1.61
22	ORPUB-13	0.73	1.07	1.18	-	1.55
23	ORPUB-23	0.58	0.97	1.17	-	1.52
24	ORPUB-24	0.53	0.82	0.91	-	1.25
25	ORPUB-26	0.53	0.85	1.19	-	1.37
$SE_{(m)\pm}$		0.04	0.06	0.06	-	0.06
$CD_{(0.05)}$		0.11	0.17	0.17	-	0.17

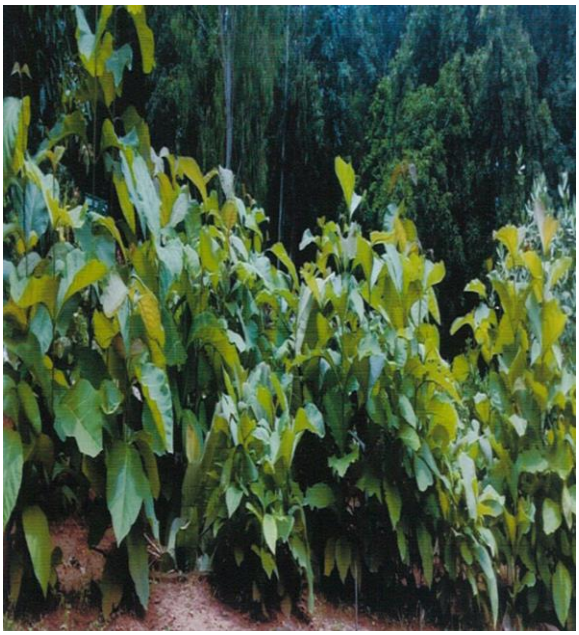

Fig. 4. Teak seedlings in Nursery experiment

Fig. 5. Uprooted seedlings for estimation of biomass and quality index

Table 3. Height growth of seedlings from open pollinated seeds of different teak clones

S. No.	Clone ID	Height (cm)				
		At 3 month after sowing	At 6 month after sowing	At 9 month after sowing	Deciduous phase	At 15 month after sowing
1	MHALA-4	16.50	23.00	29.75	-	91.80
2	MHALA-5	9.46	15.65	21.49	-	72.32
3	MHALA-7	11.50	15.78	19.55	-	60.28
4	MHALA-9	21.96	30.00	39.85	-	147.50
5	MHALP-7	13.65	20.71	26.15	-	81.09
6	MHALP-8	11.00	16.75	21.22	-	70.45
7	MHALP-9	13.75	20.50	25.55	-	76.00
8	MHEMR-1	15.64	23.33	29.12	-	89.12
9	MHEMR-2	14.65	21.43	31.65	-	112.12
10	MHSLA-2	14.81	23.63	26.55	-	85.60
11	MHWYK-3	18.62	24.81	32.23	-	103.33
12	ORAN-1	18.86	27.47	30.45	-	94.14
13	ORANP-1	15.62	22.78	29.25	-	86.27
14	ORANP-3	12.33	31.77	35.85	-	115.12
15	ORANP-4	11.19	19.00	27.66	-	83.00
16	ORANP-15	14.83	21.36	26.55	-	88.50
17	ORANR-4	12.71	18.71	21.23	-	76.77
18	ORANR-5	7.25	15.00	19.85	-	70.75
19	ORANR-6	11.29	19.00	28.55	-	85.50
20	ORPUB-2	8.30	17.60	20.25	-	61.00
21	ORPUB-10	17.62	23.48	32.25	-	103.60
22	ORPUB-13	16.50	23.45	31.55	-	100.77
23	ORPUB-23	20.25	27.60	32.25	-	100.42
24	ORPUB-24	18.25	21.68	26.50	-	85.20
25	ORPUB-26	13.23	24.00	27.73	-	73.25
$SE_{(m)\pm}$		0.75	0.83	1.29	-	2.32
$CD_{(0.05)}$		2.13	2.36	3.66	-	6.59

3.2.2 Height of seedlings

The height growth of the seedlings demonstrated significant variation among the clones at different stages of assessment (Table 3). It varied from 7.25 to 21.96 cm, 15.00 to 30.00 cm, 19.55 to 39.85 cm and 60.28 to 147.50 cm at 3, 6, 9 and 15 month after sowing, respectively. At 15 month after sowing MHALA-9 excelled in height over others and lowest performance in height growth was recorded in MHALA-7 which was similar to ORPUB-2. In all clones height of plants increased steadily towards higher age.

The variation in height growth was significant among the clones at different ages. This may be attributed to variation in rate of apical meristem growth of different clones. MHALA-9 has probably significantly higher apical meristem growth over others. Variation in height growth of different clones have also been reported by Nayak et al. [22], Mahmud and Hossain [23],Palaniswami et al. (2009) and Rao et al. [24].

3.3 Number of Leaves in Seedling

The number of leaves per seedling varied significantly among clones (Table 4). It varied from 8.00 to 11.35, 13.42 to 19.58 and 16.14 to 23.50 at 3, 6 and 9 month after sowing, respectively. At 15 month after sowing which followed the deciduous phase of winter, it ranged from 10.50 to 13.70 and MHALA 9 maintained its supremacy and recorded highest number of leaves which was of course at par with MHEMR-2. The clone MHALA-5 produced minimum number of leaves and remained at par with MHALA-4, MHALP-8, MHEMR-1, MHSLA-2, ORAN-1, ORANP-15, ORANR-4, ORANR-5, ORANR-6, ORPUB-2, ORPUB-10, ORPUB-13 and ORPUB-26.

Table 4. Number of leaves per seedling from open pollinated seeds of different teak clones

S. No.	Clone ID	Number of leaves per seedling				
		At 3 month after sowing	At 6 month after sowing	At 9 month after sowing	Deciduous phase	At 15 month after sowing
1	MHALA-4	10.00	17.12	20.15	-	12.25
2	MHALA-5	9.28	16.25	18.34	-	10.50
3	MHALA-7	11.25	18.35	21.15	-	12.50
4	MHALA-9	11.35	19.58	23.50	-	13.70
5	MHALP-7	10.05	14.60	19.78	-	13.60
6	MHALP-8	9.30	17.50	19.60	-	12.40
7	MHALP-9	9.30	16.50	21.65	-	13.50
8	MHEMR-1	8.75	16.25	19.80	-	12.00
9	MHEMR-2	11.12	18.85	22.56	-	13.70
10	MHSLA-2	9.06	15.20	18.90	-	12.00
11	MHWYK-3	10.35	16.25	22.80	-	13.40
12	ORAN-1	9.98	16.73	20.66	-	11.80
13	ORANP-1	10.50	16.50	21.80	-	12.80
14	ORANP-3	10.50	18.50	22.50	-	13.00
15	ORANP-4	10.69	17.50	20.40	-	13.10
16	ORANP-15	9.18	15.35	18.13	-	12.00
17	ORANR-4	8.02	13.42	16.14	-	11.50
18	ORANR-5	8.15	15.70	17.40	-	10.70
19	ORANR-6	9.96	17.02	21.32	-	12.40
20	ORPUB-2	10.80	15.50	18.70	-	10.60
21	ORPUB-10	9.75	15.56	20.40	-	11.50
22	ORPUB-13	10.50	15.40	18.50	-	11.50
23	ORPUB-23	9.28	16.24	20.22	-	13.50
24	ORPUB-24	9.12	15.06	19.04	-	12.50
25	ORPUB-26	9.66	17.80	22.50	-	12.40
$SE_{(m)\pm}$		0.66	0.90	1.04	-	0.67
$CD_{(0.05)}$		1.86	2.56	2.96	-	1.91

Table 5. Biomass growth of seedlings raised from open pollinated seeds of different teak clones

S. No.	Clone ID	Shoot weight of seedling (g)					Root weight of seedling (g)					Total weight of seedling (g)				
		At 3 month after sowing	At 6 month after sowing	At 9 month after sowing	Deciduous phase	At 15 month after sowing	At 3 month after sowing	At 6 month after sowing	At 9 month after sowing	Deciduous phase	At 15 month after sowing	At 3 month after sowing	At 6 month after sowing	At 9 month after sowing	Deciduous phase	At 15 month after sowing
1	MHALA-4	5.56	12.32	17.45	-	67.23	0.93	10.03	13.03	-	24.64	6.49	22.35	30.48	-	91.87
2	MHALA-5	2.15	4.85	7.94	-	31.11	0.51	5.41	6.57	-	18.85	2.66	10.26	14.51	-	40.96
3	MHALA-7	1.97	4.18	7.75	-	30.85	0.50	2.64	3.40	-	11.50	2.47	6.82	11.15	-	42.35
4	MHALA-9	8.35	18.30	27.69	-	139.39	1.81	16.45	19.89	-	46.51	10.16	34.75	47.58	-	185.90
5	MHALP-7	2.58	5.88	9.71	-	42.36	0.95	6.55	7.54	-	17.01	3.53	12.43	17.25	-	59.37
6	MHALP-8	2.25	4.86	8.04	-	35.92	0.78	4.07	5.55	-	15.43	3.03	8.93	13.89	-	51.35
7	MHALP-9	2.35	6.16	12.29	-	50.41	0.94	6.38	8.16	-	17.61	3.29	12.54	20.45	-	68.02
8	MHEMR-1	2.85	6.82	15.68	-	68.96	1.05	5.78	8.56	-	20.63	3.90	12.60	24.24	-	89.59
9	MHEMR-2	4.36	11.21	16.45	-	89.67	1.18	10.16	14.34	-	35.88	5.54	21.37	30.79	-	125.55
10	MHSLA-2	2.25	5.57	8.75	-	33.16	0.75	4.42	6.89	-	15.65	3.00	9.99	15.64	-	48.81
11	MHWYK-3	5.43	15.20	17.30	-	76.95	1.23	14.31	15.35	-	29.30	6.66	29.51	32.65	-	106.25
12	ORAN-1	5.07	8.46	12.81	-	73.29	0.93	8.95	11.35	-	22.28	6.00	17.41	24.16	-	95.57
13	ORANP-1	3.15	8.44	10.87	-	48.88	0.95	7.16	9.98	-	16.19	4.10	15.60	20.85	-	65.07
14	ORANP-3	5.90	13.45	24.90	-	100.87	1.75	10.95	14.45	-	36.76	7.65	24.40	39.35	-	137.63
15	ORANP-4	4.36	10.15	14.92	-	64.38	0.86	8.98	10.65	-	24.68	5.22	19.13	25.57	-	89.06
16	ORANP-15	3.12	8.31	10.34	-	43.47	0.95	6.53	8.30	-	32.23	4.07	14.84	18.64	-	75.70
17	ORANR-4	2.65	4.19	8.74	-	37.38	0.32	4.48	6.65	-	17.75	3.17	8.67	15.39	-	55.13
18	ORANR-5	2.68	8.65	11.35	-	46.18	0.72	6.54	10.35	-	19.95	3.40	15.19	21.70	-	66.13
19	ORANR-6	4.80	9.11	20.15	-	89.85	1.20	8.98	11.56	-	26.35	6.00	18.09	31.71	-	116.20
20	ORPUB-2	2.10	5.26	10.69	-	41.90	0.67	3.81	6.56	-	12.48	2.77	9.07	17.25	-	54.38
21	ORPUB-10	4.98	12.73	20.30	-	91.02	1.20	8.83	14.65	-	29.27	6.18	21.56	34.95	-	120.29
22	ORPUB-13	3.36	11.85	18.78	-	76.50	1.04	9.90	12.56	-	25.04	4.40	21.75	31.34	-	101.54
23	ORPUB-23	4.15	8.50	14.52	-	64.96	1.45	7.91	10.85	-	32.75	5.60	16.41	25.37	-	97.71
24	ORPUB-24	3.85	7.84	13.50		59.62	1.12	7.44	9.65		27.88	4.97	15.28	23.15		87.50
25	ORPUB-26	2.18	6.85	13.98	-	58.07	1.11	4.57	6.54	-	25.23	3.29	11.42	20.52	-	83.30
$SE_{(m)\pm}$		0.16	0.62	1.10	-	2.22	0.11	0.50	0.81	-	1.31	0.31	0.98	1.24	-	2.66
$CD_{(0.05)}$		0.44	1.75	3.13	-	6.31	0.30	1.42	2.29	-	3.72	0.89	2.78	3.53	-	7.56

The number of leaves varied significantly under different clones at particular stage because of variation in height as mentioned in Table 3. Similar finding has been reported by Nayak et al. [22] and Mahmud and Hossain [23]. The number of leaves progressively increased upto 9 month age in each clone because the height went on increasing till the deciduous phase (winter) arrived. During the deciduous phase (10-12 month) the plants remained in dormant condition and shed all leaved and produced new leaves after the spring. Therefore the number of leaves at 15 month age was less than the previous stage of evaluation i.e. 9 month age.

3.4 Biomass of Seedlings

Different clones exhibited significant variation in biomass of seedlings (Table 5). It ranged from 1.97 to 8.35g, 4.18 to 18.30g, 7.75 to 27.69g and 30.85 to 139 39 at 3, 6, 9 and 15 month after sowing, respectively. All along MHALA-9 maintained its supremacy generating significantly higher quantity of shoot biomass over others whereas MHALA-7 generated the lowest biomass. In all clones shoot weight increased progressively upto the last stage of evaluation (15 month).

Root weight of seedlings varied remarkably among the clones at different ages of seedling growth. It ranged from 0.50 to 1.81g, 2.64 to 16.45g, 3.40 to 19.89g and 11.50 to 46.51g at 3, 6, 9 and 15 month after sowing, respectively. MHALA-9 recorded maximum root biomass while MHALA-7 positioned the last recording lowest root biomass. The root biomass consistently increased up to 15 months under each clone.

The total weight of the seedling showed significant variation among the clones studied. It ranged from 2.47 to 10.16g, 6.82 to 34.75g, 11-15 to 47.58g and 42.35 to 185.90g at 3, 6, 9 and 15 month after sowing, respectively. MHALA-9 proved to be most promising securing significantly higher biomass over others at every stage of assessment. On the other hand MHALA-7 was found to be lowest performer generating minimum biomass at each stage of evaluation.

The variation of seedling biomass may be ascribed to the difference in genetic makeup of clones governing shoot growth and root growth. This has been clearly witnessed in diameter growth and height growth of the seedlings (Table 2 and 3). The variation in biomass production of different clones has been reported by Nayak et al. [22] and Mahmud and Hossain [23]. Mathew (2001) has also observed significant influence of clones on root growth and their biomass intake. Surendra et al. [12] have reported variation in seedling biomass of different populations. In all clones the biomass progressively increased upto 15 month of age which may be due to progressive enhancement of apical meristem and lateral meristem of seedlings.

3.5 Quality of Seedlings

The quality index of seedling varied significantly among clones at different stages of evaluation (Table 6). It ranged from 0.39 to 1.35, 1.93 to 9.62, 2.49 to 10.79 and 4.62 to 16.41 at 3, 6, 9 and 15 month after sowing, respectively. At 15 month after sowing. MHALA-9 excelled in producing highest quality seedling followed by ORANP- 3. MHALA-7 was found to record the lowest quality index. The order of quality index of seedling at 15 month after sowing which is very suitable age of transplantation in main field was in order of : MHALA-9 > ORANP-3 > MHEMR-2 > ORPUB-10 > ORANR-6 > MHWYK- 3 > ORPUB-23 > ORPUB-26 > ORPUB-13 > MHALA-4 > ORPUB-24 = ORAN-1 > MHEMR-1 > MHALP-9 > ORANP-4 > ORANP-15 > ORANR-4 > ORANR-5 > ORPUB-2 > MHALP-8 > MHALA-5 > MHALP-7 > MHSLA-2 > MHALA-7.

The performance of clones with regard to production of quality planting material of teak differed significantly from one another. The variation in quality of planting stock of different clones may be attributed to difference in genetic character of clones that governs the height growth, diameter growth and biomass of seedling. A wide variation in different growth parameters including biomass of seedling has already been reflected in Table 2-5. Variation in seedling quality of different teak clones has been reported by Nayak et al. [22] and Mahmud and Hossain [23].

3.6 Cluster Analysis of Clones

The 25 number of clones are classified into three clusters on basis of weight of 100 fruits, germination percent of fruits, collar diameter of seedling at 15 month, height of seedling at 15 month, total weight of seedling at 15 month and quality index of seedling at 15 month (Fig 6). These parameters positively influence the quality of seedling. The clone MHALA-9 (Serial No 4) alone is categorized as one cluster and the

remaining clones are grouped into two other clusters. MHALA-9 was found to be the best clone among the 25 clones of teak tested with regard to growth and quality of seedlings [25].

Table 6. Quality index of seedlings from open pollinated seeds of different teak clones

S. No.	Clone ID	Quality Index				
		At 3 month after sowing	At 6 month after sowing	At 9 month after sowing	Deciduous phase	At 15 month after sowing
1	MHALA-4	0.73	6.33	7.90	-	10.09
2	MHALA-5	0.39	3.17	4.27	-	6.51
3	MHALA-7	0.42	1.93	2.49	-	4.62
4	MHALA-9	1.33	9.62	10.79	-	16.41
5	MHALP-7	0.67	3.57	3.95	-	5.56
6	MHALP-8	0.62	2.72	3.37	-	6.52
7	MHALP-9	0.55	4.27	5.57	-	8.83
8	MHEMR-1	0.69	3.10	5.47	-	9.23
9	MHEMR-2	0.99	7.16	8.18	-	13.57
10	MHSLA-2	0.54	2.39	3.93	-	5.28
11	MHWYK-3	0.97	8.78	8.61	-	11.70
12	ORAN-1	0.71	4.28	5.70	-	9.77
13	ORANP-1	0.64	3.70	5.63	-	6.63
14	ORANP-3	1.35	6.04	8.40	-	14.28
15	ORANP-4	0.73	5.46	5.54	-	8.65
16	ORANP-15	0.60	3.86	4.41	-	7.87
17	ORANR-4	0.45	3.03	4.77	-	7.26
18	ORANR-5	0.61	4.75	6.32	-	7.25
19	ORANR-6	0.99	5.61	7.39	-	12.04
20	ORPUB-2	0.55	2.45	4.61	-	6.76
21	ORPUB-10	0.92	6.03	8.49	-	12.60
22	ORPUB-13	0.80	6.42	7.52	-	10.63
23	ORPUB-23	0.88	4.19	6.20	-	11.37
24	ORPUB-24	0.72	4.13	5.37	-	9.77
25	ORPUB-26	0.74	2.64	4.59	-	10.89
$SE_{(m)\pm}$		0.04	0.37	0.37	-	0.78
$CD_{(0.05)}$		0.11	1.04	1.04	-	2.21

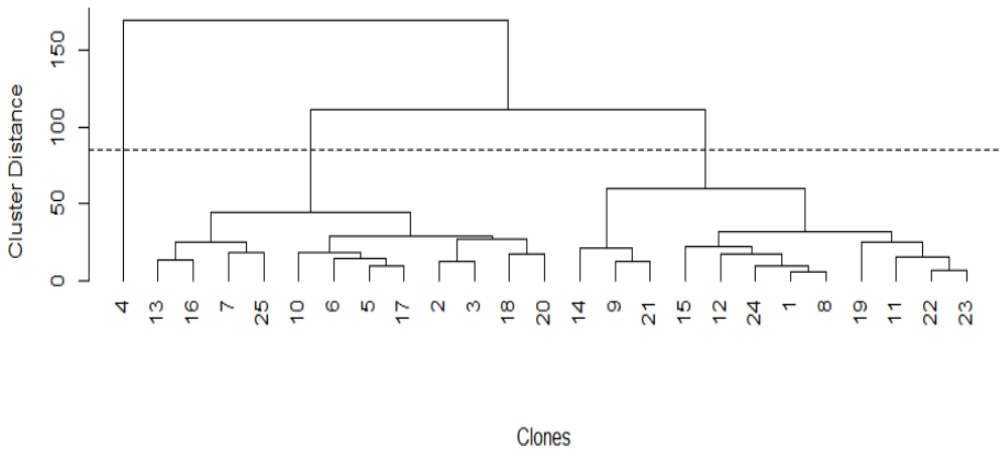

Fig. 6. Dendrogram for clustering of clones on basis weight of 100 fruits, germination percent of fruits, collar diameter of seedling at 15 month, height of seedling at 15 month, total weight of seedling at 15 month and quality index of seedling at 15 month

4. CONCLUSION

The teak clone ORANP-4 registered highest fruit length, fruit viability and germination percentage. However, ORAN-1 excelled over others with regard to fruit width and weight of 100 fruits. The clones ORAN-1, ORANR-4, ORANR-6, ORPUB-23 and ORPUB-24 registered the maximum number of seeds per fruit. A significant variation was observed at different ages of growth of the seedlings under different clones. MHALA-9 was found superior over others with regard to collar diameter, height, number of leaves, shoot weight, root weight, total weight and quality index. Overall, MHALA-9 was found to be a promising clone in producing high quality seedling from the open pollinated seeds and this may be recommended for mass planting to enhance productivity of teak in eastern India like condition.

ACKNOWLEDGEMENT

The authors duly acknowledge the State Silviculturist of Odisha, Bhubaneswar and authorities of Odisha University of Agriculture & Technology, Bhubaneswar, India for providing field and laboratory facilities for the investigation.

COMPETING INTERESTS

Authors have declared that no competing interest exist.

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