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# Variability, broad sense heritability, genetic advance of *Terminalia bellerica* (Gaertn.) Roxb progenies

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**Abstract**
The 18 progenies of *Terminalia bellerica* (Gaertn.) Roxb were tested in the field at FC&RI Mettupalayam for their phenotypic and genotypic coefficient of variance, broad-sense heritability and genetic advance for biometric and biochemical attributes such as plant height, basal diameter, volume, chlorophyll 'a', chlorophyll 'b', chlorophyll a/b ratio, total chlorophyll. The phenotypic coefficient of variance was measured larger than the genotypic coefficient of variation among the biometric and biochemical variables which indicating a significant contribution from environmental factors. Plant height and basal diameter were the superior biometric features with the highest PCV, GCV, broad-sense heritability, and genetic progress as a percentage of mean values. As a result, these parameters could be employed as selection criteria to boost the volume of *Terminalia bellerica*. Among the biochemical attributes, chlorophyll 'a' registered higher PCV, GCV, broad-sense heritability and genetic advance as percent of mean followed by chlorophyll b, Carotenoids, total chlorophyll and chlorophyll a/b ratio. As a result of the current study, variability parameters indicate that this species has a wider scope of genetic improvement.

**Keywords:** *Terminalia bellerica*, variability, broad sense heritability, genetic advance

## Introduction
*Terminalia bellerica*, often known as beleric myrobalan, is a big deciduous tree in the Combretaceae family. It is found across tropical Asia, including India. It is a versatile tree that supplies raw materials to the pharmaceutical, animal husbandry, leather, dyeing, soap, chemical, resin and gum, paper, railroads, match, oil and cosmetic sectors. It is well recognised for its antibacterial, antifungal and antimalarial properties and is often utilised in the manufacture of herbal medicines in Indian Ayurveda. The country now has 2.89 percent (9.51 million hectares) and 21.67 percent (71.22 million ha) of its land covered with trees, respectively. From 10 million m3 in the 1970s to 4 million $m^3$ in 1990, and now to 3 million $m^3$, the yearly harvest of timber from the forest has decreased. In 2020, TOF was produced 85 million $m^3$ of wood *Terminalia bellerica* annually. According to Shrivastava and Saxena (2017) [21], the total wood demand of India is 153 million $m^3$ in 2020 and the productivity of wood is only 60 million $m^3$ Shrivastava & Saxena, (2017) [21].
The genetic resources of Terminalia species have been rapidly depleted because of overgrazing, indiscriminate tree felling, conversion of forest area to farmland, human settlements and overexploitation of Terminalia for lumber, leather, and pharmaceutical industries.
For genetic diversity to be conserved and used, a greater knowledge of genetic diversity's distribution is necessary. Because it enhances the likelihood of recovering superior genotypes, genetic analysis research is more helpful in tree improvement programmes, according to (Zobel and Talbert 1984) [27]. This species has limited study and attention. As a result, the current study was developed to enhance the species through advance tree improvement programme to meet out the raw materials for the wood-based industries. In light of the fact that no research has revealed any genetic variety in *Terminalia bellerica*, the current study has been conducted.

## Materials and Methods
For this study, the species *Terminalia bellerica* was chosen as the experimental subject, and a progeny assessment trial with 18 progenies was maintaining at the Forest College and Research Institute in Mettupalayam, Coimbatore and Tamil Nadu in the years 2020-2022, with

a 4 m x 4m spacing. A total of 18 candidate plus trees were chosen from a study of the dominating *Terminalia bellerica* found in Kerala, Tamil Nadu, Karnataka, Maharashtra and Arunachal Pradesh, five separate states. These chosen CPTs were issued with the FCRI TB consent number. Table 1 included information on the actual locations of the 18 elected candidates as well as trees.

Biometric measurements such as tree height (m) and basal girth (cm) were taken at 60-day intervals for four distinct growth periods. The plant height was measured in cm from ground level to the first tip of the stem using a measuring tape. At the base of the stem, the basal diameter was measured in centimeters using a digital calliper (near the ground level). The volume index was computed using the method proposed by after measuring the plant height and basal diameter (Manavalan, 1990) [17].

By using the method of Yoshida *et al*., (1971) [24], chlorophyll is isolated in 80% acetone, and absorbance is measured in a spectrophotometer, biochemical properties such as the chlorophyll (a, b and total) as well as carotenoid content in leaves were evaluated. Calculating the quantity of chlorophyll involves using the absorption coefficients. The information was reported quantitatively in mg/gm.

With the use of a pestle and mortar, 0.25 grammes of newly obtained leaf samples from various genotypes were ground into a fine paste and extracted in 10 ml of 80% acetone. The solution was then centrifuged for 10 minutes at 3000 rpm. After being transferred to a 50 ml volumetric flask, the collected supernatant's volume was reduced to 25 ml by adding 80% acetone. Then, in the spectrophotometer, the absorbance was measured at wavelengths of 480, 510, 645, 652 and 663 nm in comparison to a blank (80% acetone). Using the formulae, the quantity of chlorophyll and carotenoids in the leaf extract was determined by calculating the absorbance of samples obtained at various wavelengths.

The method provided by Johnson *et al.* (1955) [9] was used to evaluate genetic characteristics such as Phenotypic and Genotypic variances. Phenotypic and Genotypic coefficients of variation (PCV and GCV) were calculated by (Burtons 1952) [3]. According to Lush (1940) [16], heritability was estimated in a broad sense (1940). Following Johnson *et al*., (1955) [9], a genetic advance was devised.

**Statistical analysis**

Statistical analysis for this study was carried out using TNAUSTAT and AGRESS.

**Results and Discussion**

The mean values of the biometric parameters, including plant height (m), basal diameter (cm), total chlorophyll (mg gm-1), chlorophyll a/b ratio, and carotenoids (mg gm-1), of 18 genotypes were measured at the Mettupalayam Forest College and Research Institute. These data are shown in Table 2.

Height is a crucial growth attributes which indicate the site quality. The genotypes with the highest reported heights (7.19 m) were FCRI TB 17, FCRI TB 16, and FCRI TB 10 (7.17 m and 7.04 m, respectively). The FCRI TB 12 (6.23 m) and FCRI TB 04 (6.24 m) had the lowest heights, respectively (6.29m). Different *Terminalia bellerica* genotypes' plantations, which are 24 months old, range in height from 6.23m to 7.19m. FCRI TB 03 genotype, out of the 18 genotypes examined, had the largest basal diameter, measuring 50.85 cm, followed by the FCRI TB 10 genotype, whose basal diameter was 49.45 cm. The FCRI TB 14 (39.16 cm) and FCRITB 12 (40.28 cm), which are comparable, demonstrated the smallest basal diameter.

Among the observations made, it was discovered that FCRI TB 05, which has greater levels of chlorophyll "a" (1.127 mg gm-1), chlorophyll "b" (0.979 mg gm-1), and carotenoids value, has also attained maximum height (7.19 m) and basal diameter (41.99 cm). This outcome agreed with the research of Larekeng *et al.*, (2019) [15]. He demonstrated that the amount of chlorophyll directly correlates with plant growth and development and sustains the photosynthesis process. A leaf with a greater chlorophyll concentration would be more effective at absorbing sunlight for increased photosynthetic energy generation. The trees use the energy produced for the process of growth and development. High chlorophyll concentration will therefore increase the pace of photosynthetic growth, which will improve the yield's quality and quantity as well as its nutritional content (Larekeng *et al*., 2019) [15].

Next, heritability and genetic advance as a percentage of mean for the biometric and physiological parameters of *Terminalia bellerica* were computed, and the results of genetic estimates, including phenotypic coefficient of variation, genotypic coefficient of variation, and genetic advance, were displayed in table 3. For the chlorophyll 'a' detected, the phenotypic and genotypic coefficients of variation were 26.75% and 23.15%, respectively. With 92.61% and 41.69 percent, respectively, the heritability and genetic progress as a percentage of mean were determined to be high. The PCV and GCV of the chlorophyll "b" were observed to be 23.47 and 19.10, respectively. For this variable, heritability and genetic progress as a proportion of the mean were both high (91.52% and 43.44, respectively).

The genetic analysis for biometric and physiological variables, including broad-sense heritability, genetic advance, and phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), is described in Table 3.

Plant Height, Basal Diameter, and Volume are the three biometric parameters. The genotypic and phenotypic coefficient of variation for plant height was modest. The plant height had genotypic and phenotypic values of 15.35 and 13.87, respectively. The mean percentages of genetic increase and high heritability for plant height were 99.64% and 30.99%, respectively. For basal diameter, the phenotypic and genotypic coefficients of variation were 6.34 and 2.33 percent of the mean, respectively. Plant height exhibited the highest broad sense heritability (99.64%) and the largest genetic progress as a percentage of the mean by volume (49.97%) among the three biometric characteristics. The volume exhibited high broad-sense heritability and strong genetic progress as percent of mean 78.00% and 49.97%, correspondingly, as well as high phenotypic and genotypic coefficients of variation of 28.71 and 27.05 percent, respectively. The phenotypic coefficient of variance (PCV) is greater than the genotypic coefficient of variation among the three biometric traits (GCV).

Chlorophyll "a" had the highest broad-sense heritability of 92.61 and genetic advance of 41.69 percent among the biochemical characteristics. It also had the highest values for the phenotypic coefficient of variance and genotypic coefficient of variance, which were 26.75 and 23.15 percent, respectively. The phenotypic coefficient of variation (PCV) and genotypic coefficient of variance (GCV) for chlorophyll 'b' were both 23.47 and 19.10 percent, respectively. It had a genetic advance rate of 43.44 percent and a broad-sense heritability rate of 91.52 percent. Among the biochemical characteristics, total chlorophyll showed the lowest

phenotypic and genotypic coefficients of variation. It has a reported PCV of 13.96%, a GCV of 8.61%, a low genetic advance of 11.54% and low broad-sense heritability of 67.62%. Among the biochemical characteristics, the chlorophyll a/b ratio and carotenoids showed a medium phenotypic coefficient of variance and genotypic coefficient of variance. Carotenoids and the chlorophyll a/b ratio exhibited respective PCV and GCV values of 11.17 and 20.59 percent and 8.53 and 17.02 percent. A 17.51 percent genetic progress and a medium broad-sense heritability of 69.98% were observed for the chlorophyll a/b ratio. The broad-sense heritability of carotenoids was high (89.33%) and the genetic progress was moderate (32.13%). The highest PCV and GCV for volume were 28.71% and 27.05%, respectively, while the greatest broad sense heritability for plant height was 99.64% and the maximum genetic advance by volume was 45.15% percent of the mean among the biometric and biochemical parameters.

According to Zobel (1971) [26], one key instrument in the tree improvement programme is the estimate of genetic variation. Isolating better progenies is a prerequisite for obtaining a higher yield if a population's variability is mostly due to genetic causes with little environmental influence (Islam and Rasul, 1998) [8]. The base population's level of variability, which may be measured using a variety of indices such as phenotypic and genotypic variances and phenotypic and genotypic coefficient of variances, is essential to the strategy for breeding trees.

When the biometric and biochemical traits, including plant height, basal diameter, volume index, chlorophylls 'a' and 'b, chlorophyll a/b ratio, total chlorophyll, and carotenoids, were examined in the current study, it became clear that there was significant variation among the various *Terminalia bellerica* progenies.

Among the biometric measurements, volume exhibited the highest heritability, followed by basal diameter and plant height. *Simarouba glauca* research findings that concur with earlier findings have been presented (Kumaran *et al*., 2010); *Melia dubia* [14] (Saravanan, 2012) Eucalyptus [20] (Balaji, 2000) *Azadirachta indica* [2] (Dhillon *et al*., 2003) [5]; *Santalum album*; *Leucaena leucocephala* (Chavan and Keerthika, 2013) (Krishnakumar, 2017) *Neolamarkcia cadamba*, [12] (Thirunirai Selvan *et al*., 2018) [23]. The benefits of tree breeding programmes are determined by the type and degree of genetic diversity. The highest gains are for features with a wide range of variation and a strong genetic component (Zobel, 1971) [26]. According to Dorman (1976) [6], heritability is particularly important in tree improvement programmes. In a cross-breeding strategy, it's also useful for figuring out the relative importance of each character.

The qualities with the most potential for improvement are those with high genetic diversity and strong genetic impact. As demonstrated in prior publications of poplars and Prosopis cineraria (Tiwari *et al*., 1993 and Singh *et al*., 2001) [24], characteristics with a high heritability and a large genetic gain might be utilised as reliable markers. Because of the high heritability and large genetic gain for volume in the current study, it was concluded that genetics has a major impact on this trait.

The relative values of the genotypic and phenotypic coefficients of variation may be used to calculate the amount of diversity present in a genetic population. The importance of the environment in determining how characteristics are expressed is demonstrated by the fact that numerous traits had genotypic estimates that were lower than the Phenotypic Coefficient of Variance in the current research. The estimations of the study's variability parameters closely match those of *Pongamia pinnata* genetic parameters (Kumaran, 1991) *Santalum album* [13]; (Krishnakumar, 2017) *Neolamarkcia cadamba* [12], (Thirunirai Selvan *et al*., 2018) *Ailanthus excelsa* [23] (Kanna *et al*., 2019) [10] *Azadirachta indica* (Mathivanan *et al*., 2021).

The substantial genotypic variance and phenotypic coefficient of variation were noted at the volume index. Similar results were seen in Teak (Arun Prasad, 1996) [1], as well. Poor phenotypic and genotypic coefficients of variation for height and basal diameter were also seen in *Bambusa pallida* (Singh and Benewal, 1993). According to Krishnakumar *et al*., (2017) [12], the PCV and GCV of Plant height, Basal Diameter and Volume observed in this study provided evidence for the existence of sufficient genotypic variations that may be used to further enhance crops.

The highest phenotypic and genotypic coefficients of variation, as well as high heritability and genetic progress, were recorded for chlorophyll 'a', followed by chlorophyll 'b', carotenoids, the chlorophyll a/b ratio, and total chlorophyll content. The findings of the current investigation in *Ailanthus excelsa* are highly supported by (Kanna *et al*. 2019) [10].

**Table 1:** Locations of the selected CPT's

| S. No. | Sources | District | State | Latitude | Longitude | Assigned name |
|---|---|---|---|---|---|---|
| 1. | Bandipur Tiger Reserve & National Park | Bandipur | Karnataka | 11.6645 | 76.6264 | FCRI TB 1 |
| 2. | Bandipur Tiger Reserve & National Park | Bandipur | Karnataka | 11.6645 | 76.6264 | FCRI TB 2 |
| 3. | Mysuru Zoo | Mysuru | Karnataka | 12.3005 | 76.6696 | FCRI TB 3 |
| 4. | KAU | Thrissur | Kerala | 10.3832 | 76.3296 | FCRI TB 4 |
| 5. | KAU | Thrissur | Kerala | 10.3836 | 76.3299 | FCRI TB 5 |
| 6. | Vellanikkara | Thrissur | Kerala | 10.5482 | 76.2789 | FCRI TB 6 |
| 7. | Vellanikkara | Thrissur | Kerala | 10.5480 | 76.2787 | FCRI TB 7 |
| 8. | Vellanikkara | Thrissur | Kerala | 10.5482 | 76.2788 | FCRI TB 8 |
| 9. | Bentham and Hooker Garden | Thrissur | Kerala | 10.5479 | 76.2787 | FCRI TB 9 |
| 10 | Bentham and Hooker Garden | Thrissur | Kerala | 10.5486 | 76.2788 | FCRI TB 10 |
| 11 | Akola | Akola | Maharashtra | 20.7030 | 77.0692 | FCRI TB 11 |
| 12 | Akola | Akola | Maharashtra | 20.7030 | 77.0693 | FCRI TB 12 |
| 13 | Akola | Akola | Maharashtra | 20.7030 | 77.0699 | FCRI TB 13 |
| 14 | Shioni | Bhandara | Maharashtra | 20.7029 | 77.0701 | FCRI TB 14 |
| 15 | Patur | Akola | Maharashtra | 20.7029 | 77.0701 | FCRI TB 15 |
| 16 | Jagnari slopes | Coimbatore | Tamil Nadu | 11.3233 | 76.9349 | FCRI TB 16 |
| 17 | Shevroy hills | Salem | Tamil Nadu | 11.8474 | 78.2284 | FCRI TB 17 |
| 18 | Pasighat | Eastsiang | Arunachal Pradesh | 28.0758 | 95.3259 | FCRI TB 18 |

**Table 2:** Biometric and physiological parameters of 18 *Terminalia bellerica* progenies

| Source Name | Height (m) | Basal diameter (cm) | Volume ($m^3$) | Chlorophyll 'a' (mg $gm^{-1}$) | Chlorophyll 'b' (mg $gm^{-1}$) | Total Chlorophyll (mg $gm^{-1}$) | a/b ratio | Carotenoids (mg $gm^{-1}$) |
|---|---|---|---|---|---|---|---|---|
| FCRI TB 01 | 6.5 | 44.24 | 0.6916 | 0.628 | 0.435 | 0.754 | 1.063 | 0.561 |
| FCRI TB 02 | 6.67 | 43.61 | 0.6897 | 0.552 | 0.213 | 0.690 | 0.765 | 0.645 |
| FCRI TB 03 | 6.73 | 50.85 | 0.6312 | 0.515 | 0.278 | 0.654 | 0.793 | 0.574 |
| FCRI TB 04 | 6.29 | 41.64 | 0.6253 | 0.771 | 0.398 | 0.798 | 1.169 | 0.513 |
| FCRI TB 05 | 6.53 | 43.37 | 0.6268 | 1.127 | 0.979 | 1.943 | 2.106 | 0.518 |
| FCRI TB 06 | 6.39 | 41.9 | 0.5941 | 0.826 | 0.613 | 0.891 | 1.439 | 0.663 |
| FCRI TB 07 | 6.65 | 44.38 | 0.775 | 0.926 | 0.701 | 1.012 | 1.627 | 0.513 |
| FCRI TB 08 | 6.53 | 44.38 | 0.72 | 0.519 | 0.298 | 0.649 | 0.817 | 0.604 |
| FCRI TB 09 | 6.8 | 47.64 | 0.711 | 0.892 | 0.594 | 0.904 | 1.486 | 0.416 |
| FCRI TB 10 | 7.04 | 49.45 | 0.6626 | 0.836 | 0.534 | 0.897 | 1.37 | 0.831 |
| FCRI TB 11 | 6.63 | 46.7 | 0.6475 | 0.823 | 0.497 | 0.919 | 1.32 | 0.498 |
| FCRI TB 12 | 6.23 | 40.28 | 0.613 | 0.562 | 0.301 | 0.619 | 0.863 | 0.364 |
| FCRI TB 13 | 6.55 | 41.71 | 0.6905 | 0.997 | 0.923 | 1.009 | 1.92 | 0.574 |
| FCRI TB 14 | 6.94 | 39.16 | 0.6157 | 0.615 | 0.464 | 0.710 | 1.079 | 0.618 |
| FCRI TB 15 | 6.73 | 42.06 | 0.6391 | 0.436 | 0.254 | 0.593 | 0.69 | 0.818 |
| FCRI TB 16 | 7.17 | 42.45 | 0.8187 | 0.513 | 0.294 | 0.604 | 0.807 | 0.498 |
| FCRI TB 17 | 7.19 | 41.99 | 0.7077 | 0.612 | 0.454 | 0.784 | 1.066 | 0.886 |
| FCRI TB 18 | 6.41 | 43.73 | 0.7314 | 0.489 | 0.254 | 0.501 | 0.743 | 0.372 |

**Table 3:** Genetic estimation of 18 *Terminalia bellerica* progenies

| | PCV | GCV | Heritability | GA (%) |
|---|---|---|---|---|
| Plant height | 15.35 | 13.87 | 99.64 | 30.99 |
| Basal diameter | 6.34 | 4.61 | 63.00 | 7.63 |
| Volume | 28.71 | 27.05 | 78.00 | 49.97 |
| Chlorophyll 'a' | 26.75 | 23.15 | 92.61 | 45.69 |
| Chlorophyll b' | 23.47 | 19.10 | 91.52 | 43.44 |
| Total chlorophyll | 13.96 | 8.61 | 67.62 | 11.54 |
| a/b ratio | 11.17 | 8.53 | 69.98 | 17.51 |
| Carotenoids | 20.59 | 17.02 | 89.33 | 32.13 |

## Conclusion

The plant height and basal diameter were the two traits with the lowest phenotypic and genotypic coefficients of variation, respectively and were followed by volume. Chlorophyll 'a', Chlorophyll 'b', Total Chlorophyll, Chlorophyll a/b ratio and carotenoids content all had high PCV and GCV values. It was shown that biometric measurements such plant height, volume and basal diameter exhibited moderate genetic progress as a percentage of mean and strong broad sense heritability. Carotenoids concentration, chlorophyll 'a', chlorophyll 'b', total chlorophyll, chlorophyll a/b ratio and heritability all exhibited high to moderate genetic progress.

## Reference


1. Arun Prasad KCA. Variability studies in teak (*Tectona grandis* Linn. F.) M.Sc. (For) Thesis, Tamil Nadu Agricultural University, Coimbatore; c1996.
2. Balaji B. Estimation of genetic parameters and genetic diversity using morphometric, isozyme and RAPD approaches in *Eucalyptus tereticornis* Sm (Doctoral dissertation, Ph.D. Thesis, Tamil Nadu Agricultural University, Coimbatore); c2000.
3. Burton GW. Quantitative inheritance in grasses. Pro VI Int. Grassl. Cong; c1952. p. 277-283.
4. Deepanjali. Studies on variabilities and propagation techniques of *Toona ciliata* M. Roem under Punjab conditions, M.Sc. thesis, Punjab agricultural university, Ludhiana; c2018.
5. Dhillon RS, Bisla SS, Arya S, Hooda MS. Genetic variation, heritability and correlations for growth parameters in *Azadirachta indica* A. Juss. Annals of Forestry. 2003;11(2):215-221.
6. Dorman KW. The genetics and breeding of southern pines (No. 471). US Department of Agriculture, Forest Service; c1976.
7. Hatchel GE. Biomass research. Proc. Third biennial southern silvicultural Res. Conf. Atlanta, Georgia, November, 7-8. General technical Report, Southern Forest Experiments, Station, USDA forest service. 1984-1985;54:395-402.
8. Islam MS, Rasul MG. Genetic parameters, correlations and path coefficient analysis in groundnut. Bangla. J Sci. Ind. Res. 1998;33:250-254.
9. Johnson HW, Robinson HF, Comstock RE. Estimates of genetic and environmental variability in soybeans. Agronomy journal, 1955;47(7):314-318.
10. Kanna SU, Krishnakumar N, Kather MMA, Jailani K. Growth performance of *Ailanthus excelsa* through progeny test; c2019.
11. Krishnakumar N, Parthiban KT, Umesh Kanna S. Identification of pollinators for good quality seed productions in sandal wood (*Santalum album* L.). J Entomol Zool Stud. 2018;6(3):1467-1470.
12. Krishnakumar N, Parthiban KT, Jayamani P, Revathi R, Umeshkanna S. Genetic variability of growth parameters among different progenies of *Santalum album* L. Journal of the Indian Society of Coastal Agricultural Research. 2017;35(1):56-63.
13. Kumaran K. Genetic analysis of seed and juvenile seedling attributes in neem (*Azadirachta indica* A. Juss.), and pungam (*Pongamia pinnata* Linn. Pierre). M.Sc. (For.) Thesis, Forest College and Research Institute, Tamil Nadu Agricultural University, Coimbatore; c1991.
14. Kumaran K, Nesamani K, Rao MG. Correlation and path coefficient studies in *Simarouba glauca* DC. Indian Forester. 2010;136(3):322-330.
15. Larekeng SH, Restu M, Arsyad MA. Observation of morphological and physiological characteristics on Abangares Mahogany (*Swietenia macrophylla* King.) In South Sulawesi. In IOP Conference Series: Earth and Environmental Science IOP Publishing. 2019;270(1):012022.
16. Lush JL. Intra-sire correlations or regressions of

offspring on dam as a method of estimating heritability of characteristics. Journal of animal science. 1940;(1):293-301.
17. Manavalan A. Seedling vigor and bio productivity in woody biomass species. Ph.D. thesis, Madurai Kamuraj Univ., Madurai (India); c1990.
18. Rai SN, Chakrabarti SK. Demand and supply of fuelwood and timber in India. Indian Forester. 2001;127(3):263-279.
19. Sangram C, Keerthika A. Genetic variability and association studies among morphological traits of *Leucaena leucocephala* (Lam.) de Wit. Genetic resources; c2013.
20. Saravanan V. Genetic evaluation and wood characterization of *Melia dubia* for pulp, anatomical, mechanical, and energy properties (Doctoral dissertation, Ph.D. Thesis, Tamil Nadu Agricultural University, Coimbatore); c2012.
21. Shrivastava S, Saxena AK. Wood is good: But, is India doing enough to meet its present and future needs. Centre for Science and Environment, New Delhi; c2017.
22. Singh NB, Beniwal BS. Variability, heritability and genetic gain of some growth characters in *Bambusa balcooa*. Indian Forester. 1993;119(3):205-210.
23. Thirunirai SR, Parthiban KT. Genetic variability, correlation and path analysis in *Neolamarckia cadamba* (Roxb.) Bosser. Indian Journal of Agroforestry 2018;20(2):20-24.Tiwari DN. Poplar. Surya Publications, Dehradun, India; c1993.
24. Yoshida S, Forno DA, Cock JH. Laboratory manual for physiological studies of rice. Laboratory manual for physiological studies of rice; c1971.
25. Zhan X, Li P, Hui W, Deng Y, Gan S, Sun Y, *et al*. Genetic diversity and population structure of *Toona ciliata* revealed by simple sequence repeat markers. Biotechnology & Biotechnological Equipment. 2019;33(1):214-222.
26. Zobel BJ. The genetic improvement of southern pines. Scientific American. 1971;225(5):94-103.
27. Zobel B, Talbert J. Applied Forest tree improvement. John Wiley & Sons; c1984.