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Evaluation of the half sib progeny of selected *Melia dubia* Cav. population based on its morpho physiological characters

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Abstract
Melia dubia Cav. commonly known as Malabar neem, is a fast growing indigenous species. It is put into various medicinal uses, packing cases, cigar planks etc. The evaluation of seedling progenies from twenty five plus trees were done in nursery for five months. Significant differences among the progenies of selected trees were studied for various morphological and physiological characters. The performance of the progeny of two trees from Tholpetty (Accession No. FCV-MD-03 and FCV-MD-04) were the best. The genetic analysis of the causes of variation for morphological and physiological traits were also studied. The values for phenotypic coefficient of variation ranged from 12.62 percentage for height to 24.53 percentage for biovolume. The result showed that the values for genotypic coefficient of variation were less than phenotypic coefficient of variations for the traits studied, indicating existence of environmental effect on these characters. Heritability estimates in broad sense were observed higher than 50 percentage for quantitative characters such as height, collar diameter, number of leaves, AGR and biovolume. The correlation studies on morphological and physiological characters showed that height was positively correlated with morphological and physiological characters studied except leaf temperature. This work throws light on useful information for Melia breeding, and its germplasm resource management.

Keywords: Heritability estimates, collar diameter, number of leaves

Introduction
Melia dubia Cav. synonym Melia composita belonging to the family Meliaceae is a tree species indigenous to India and neighbouring countries like, Sri Lanka, Malaysia, Java, China, Japan and Australia (Kumar & Aiswarya, 2017) [28]. It is a huge deciduous fast growing species and is distributed in semi evergreen and moist deciduous forests of India (Nair, 1991). The tree grows up to 25 m in height with a straight bole of about 5 to 12 m and nearly 1.5 m in girth at breast height (Rawat *et al*. 2018). It coppices well and when the roots get injured it produces enormous roots. Pollarding ability is observed to be good, and a large number of new shoots emerge out from dormant buds (Kumar *et al*. 2013) [30]. The tree is found to have a tremendous adaptability to different climatic conditions (Kumar *et al*. 2017) [28]. Though the tree grows well on a variety of soils, it prefers deep fertile sandy soils. The wood is of high demand for plywood and paper industries, as it is an important alternative species for supplying the raw material for these industries (Saravanan *et al*. 2013). It is preferred in the paper industry because of increased pulp recovery, exceptional strength, and anti-termite property (Suresh & Devakumar, 2017). Parthibankt *et al*. (2009) [46] recorded 50 per cent pulp recovery for this species, which was found to be better than other major pulp yielding species. It was also observed in this study that the Kappa number, which measures the bleachability of the pulp was less than 20, which is best in comparison to the other conventional raw material (Saini *et al*. 2007). The wood is utilized for match boxes, packing cases, agricultural implements, cigar boxes, ceiling planks, splints, pencils and catamarans. It is also suitable for making musical instruments and tea boxes. The plant is put into various medicinal uses as it possesses anthelmintic, antiviral, carminative, antineoplastic properties (Vijayan *et al*. 2004; Susheela *et al*. 2008; Kiritkar *et al*. 1999). It is used for the preparation of traditional medicines for the treatment of leprosy, eczema, asthma, malaria, fevers and venereal disease, as well as cholelithiasis, acariasis and pain (Govindachari, 1992). In Indian folk medicine, it is used to control insect pests (Koul *et al*. 2000). Leaves of *Melia dubia* are excellent fodder for ruminants as they are a rich source of mineral elements, crude proteins and vitamins (Leela *et al*. 2016). Melia is also grown as shade trees in coffee and tea 46 plantations. In addition, it has

the potential to degrade commonly occurring pesticides in soil when grown along with Trichoderma viridae (Subasini *et al*. 2007) [57]. All these qualities make melia a preferable tree species for plantation and in the homesteads.

Genetic diversity is an important factor for adaptation and resistance to abiotic and biotic, further it is required in domestication and in breeding populations as these populations provide opportunity for breeders to develop new and improved breeds with desirable characteristics (Zhang *et al*. 2002) [64]. In a breeding program, progeny tests are usually done to find the genetic worth of selected plus trees. Its main advantage is to estimate the relative genetic values of parents based on the performance of their offspring (White *et al*. 2007). The half sib progeny test is done with the open pollinated seeds collected from the plus trees, which has many advantages such that it is easier, cheaper and yields results several years before the results generated by full sib progeny test (Bedell, 2006). Study done to evaluate genetic variations among open pollinated families of selected plus trees in *M. dubia* indicated the existence of adequate genetic divergence (Kumar *et al*. 2013) [30]. Usually, evaluation of the progeny is done based on its morphological characters. The studies on the variation in the physiological characters and their relationship with growth traits is meager. Such studies however help us understand underlying processes and responses and will be useful in tree improvement programs (Huang *et al*. 2019) [21].

Melia dubia a species with multi-various uses has gained only limited research attention especially with inference to tree improvement. It holds good potential for various industrial utilities and is also amenable for agroforestry and farm forestry. Lack of sufficient studies in terms of family selection, evaluation and identification of potential genetic resources necessitated the current study to select and analyze potential open pollinated families by assessing the existing variability. Thus, the object of the present study is to evaluate the half sib progeny of the selected melia population based on its physiological and morphological characters.

Materials and Methods

The experimental materials for this study consisted of 25 genotypes of melia selected from different locations in Kerala part of India (Table 1). The evaluation experiments were carried out in the nursery of College of Forestry, Kerala Agricultural University, Kerala located at 10º31'N latitude with an elevation of about 22.25 m above mean sea level during 2017-19.

Yellow coloured ripened fruits were collected directly from the selected twenty-five plus trees. They were immediately transported to the nursery in gunny bags. The fruits were soaked in acidic water for a few days for fermentation. The fermented fruits were macerated manually by rubbing on a hard surface. After depulping, the seeds were dried in shade for two days. Later the seeds were mixed with cow dung and dried for ten days in the sun so that the hard coat of the fruits cracked. The seeds were then extracted from the fruits using a nutcracker. The extracted seeds were treated in 250 mg l^{-1} gibberellic acid overnight. The seeds treated were sown in the tray filled with sand. After germination, healthy seedlings were pricked out and transplanted to the polythene bags (15 cm x 25 cm and gauge 250 mm).

The potting media used for the experiment was a combination of soil, sand and farmyard manure, in the ratio of 2:1:1. The seedlings were then kept in the nursery under 25 per cent shade. The experiment was done in a completely randomised block design with three replications. In each replication, there were five seedlings. The seedlings were evaluated for the growth and physiological parameters in the nursery for five months. In total 375 seedlings were maintained in the nursery. The seedlings height, collar diameter, the total number of leaves retained and which were functional were counted. The biovolume index (Hatchell, 1985) [20] was also estimated at the end of the study period. The physiological parameters like the chlorophyll content (SPAD-502, Minolta), photosynthetic, stomatal resistance, transpiration rate (LI-6400, LICOR Inc., Nebraska), and Relative Water Content (RWC) of seedlings were measured.

Variability studies

These parameters were measured by the method developed by Johnson *et al*. (1955) [25]. Genotypic Variance (G.V) (s^2g) = (s^2g - s^2e)/r. Where, s^2g = Genotypic mean square, s^2e = Error variance, r = Number of replications.

Phenotypic Variance (P.V) (s^2p) = s^{2g}+ s^2e. Where, s^2g = Genotypic variance, s^2e = Error variance.

Phenotypic (PCV) and genotypic (GCV) coefficients of variability were computed using the following equations suggested by Burton and De-Vane (1953).

Phenotypic Co-efficient of Variability PCV (%) = (s^2p) x 100µ µ = Population mean for each trait.

Genotypic Co-efficient of Variability.

Genotypic Co-efficient of Variability was calculated as given below GCV (%) = (s^2g) x 100 µ

Environmental coefficient of variation (ECV). It is an estimate of the total environmental variation present for a character. ECV (%) = (s^2e) x 100 µ.

Broad sense heritability (H^2)

Broad sense heritability (H^2), which is a measure of the amount of phenotypic variance contributed by genetic factor was estimated as per the formula developed by Lush (1940) [34].

$H^2 = s^2g/s^2p$

Heritability percentage = H^2 x 100

Genetic advance

Genetic advance is the increase in the magnitude of a specific character, which is expected when a selection pressure of chosen intensity is applied. The expected genetic advance at 5 per cent selection intensity was calculated as developed by Johnson *et al*. (1955) [25]. The genetic advance was calculated as:

Genetic advance (GA) = $[(s^2g)/(s^2p)] \times k \times (s^2p)$

Where, Selection intensity (k) was presumed to be 2.06, the value is considered to be normal in case of 5 per cent selection in samples which are large and are from a normally distributed population (Allard, 1960) [1].

Genetic advance as a percentage of mean was calculated using the formula given by Johnson *et al*. (1955) [25].

GA as a percentage of mean = GA/Grand mean x 100

In order to study the genetic divergence in the population of melia, hierarchical cluster analysis was done for the data collected for different growth parameters. Clustering method of between groups linkages was applied which takes into consideration squared Euclidian distance between groups. Dendrogram and a proximity matrix were also generated.

For the evaluation of progeny, final data of the experiment were subjected to one-way Analysis of Variance (ANOVA). Based on the result of ANOVA of all data, the means were separated using post-hoc analysis in the form of Duncan's Multiple Range test (Duncan, 1955) [15] to separate the means. The data gathered from the nursery were analysed and tabulated. Mean, variance and standard error were estimated as per the procedure described by Panse and Sukhatme (1978).

Results

Growth performance

Progenies from all the plus trees differed significantly for all the growth characteristics which were investigated at the end of the experiment. FCV-MD-03, FCV-MD-04 (198.7 cm) registered higher tree height followed by FCV-MD-11 (182.9 cm) and FCV-MD-12 (181.3 cm), which were higher when compared to the general mean (157.2 cm) at 1% level of significance (Table 2). Similar result was also observed for the collar diameter. FCV-MD-03 (1.54 cm), FCV-MD-04 (1.61 cm) showed the highest value followed by FCV-MD-16 (1.42 cm). These values were higher than the mean value (1.19) recorded for collar diameter. The highest values FCV-MD-03 (3.23 cm day-1) and FCV-MD-04 (3.1 cm day^{-1}) were observed for the progeny of the plus trees for the absolute growth rate. The bio-volume of the seedlings also showed similar results (Table 2).

Physiological parameters

Significant differences in photosynthetic rate, transpiration rate, chlorophyll content, leaf temperature, stomatal conductance and relative water content were observed for the seedlings of the progenies from different plus trees at 150 DAT (Table 3). The highest value for chlorophyll content (51.6 mg g^{-1}) was obtained for the seedlings of plus tree FCV-MD-03, followed by (49.4 mg g^{-1}) for the seedlings of plus tree FCV-MD-04. The lowest values were recorded (33.3 mg g^{-1}) for the seedlings of plus tree FCV-MD-11 and FCV-MD-13 (35.7 mg g^{-1}). The photosynthetic rate of the seedlings of the plus tree FCV-MD-04 were the highest (3.56 µmol m-2 s^{-1}) followed by the value (2.8 µmol m-2 s^{-1}) for the plus tree FCV-MD-03.

The lowest value (0.29 µmol m-2 s^{-1}) was observed for plus tree FCV-MD-13. The highest stomatal conductance was observed for the progenies of the plus tree FCV-MD-03 (0.27 s cm^{-1}) and FCV-MD-04 (0.23 s cm^{-1}) and the lowest value (0.01 s cm^{-1} s cm^{-1}) was observed for the progenies of the plus trees FCV-MD-11 and FCV-MD-12, the accessions were from Thiruvazhiyadu and Walayar. The transpiration rate was on par except for the seedlings of plus trees FCV-MD-02, FCV-MD-03, FCV-MD-04, FCV-MD-05, FCV-MD-15, FCV-MD-20, FCV-MD-21, FCV-MD-22 for the period 150 DAT. The value was highest for the seedlings from the plus tree FCV-MD-03 (3.49 µmol m-2s^{-1}) followed by the plus tree FCV-MD-04 (2.96 µmol m-2s^{-1}). The lowest value (0.33 µmol m-2s^{-1}) was observed for the seedlings of plus trees FCV-MD-10, FCV-MD-11, FCV-MD-12, FCV-MD-13. Leaf temperature for the seedlings of plus trees FCV-MD-09, FCV-MD-10, FCV-MD-11, FCV-MD-12, FCV-MD-13, was on par for the period 150 DAT. The highest leaf temperature was observed for the seedlings of plus trees FCV-MD-11 (37.1 ºC) and the lowest value was observed for the seedlings of plus tree FCV-MD-15 (31.15 ºC). The highest relative water content was observed for the seedlings FCV-MD-03 (89) and FCV-MD-03 (88). The lowest value (73) was obtained for the leaves of the seedlings from plus trees FCV-MD-08, FCV-MD-09. The relative water content of the leaves of the seedlings of plus trees FCV-MD-03, FCV-MD-04, FCV-MD-21 and FCV-MD-24 was on par. It was observed that the chlorophyll content, photosynthetic rate, stomatal conductance, transpiration rate and relative water content were found to be highest for the seedlings of plus trees FCV-MD-03 and FCV-MD-04, whereas the lowest value was observed for the seedlings from plus tree FCV-MD-11 and FCV-MD-14. Leaf temperature was found to be more for the seedlings of plus trees FCV-MD-11.

Genetic parameters for morphological and growth traits

The genetic parameters for morphological and growth traits after 150 DAT (Table 3) shows that the broad-sense heritability for shoot height was 0.91. It was observed that the PCV, GCV and ECV were 12.62, 12.01 and 3.87 respectively. The genetic advance was 36.53 and genetic gain 23.55. For collar diameter, the broad sense heritability was observed to be 0.53.

The PCV, GCV and ECV values being 13.98, 10.18 and 9.58 respectively. Genetic advance for this trait was 0.18 and genetic gain was 15.26. The genetic advance for this character was observed to be highest when compared to the values for other traits. Broad sense heritability for the number of leaves was observed to be 0.65. The values for PCV, GCV and ECV were observed to be 13.45, 10.88 and 7.9 respectively. The genetic advance for the number of leaves was 4.24 and genetic gain 18.15. The broad sense heritability for this trait was 0.83. The values for PCV, GCV and ECV were observed to be 18.28, 16.65 and 7.54 respectively. The value for genetic advance was 0.72 and genetic gain 31.25. The lowest value for the genetic advance was observed for this trait. The broad sense heritability for this trait was 0.84. The value for the genetic advance was 792.58 and genetic gain 42.29. The highest values for the genetic gain and genetic advance were observed for this trait. The genetic parameters for the physiological traits of seedlings 150 DAT (Table 3) showed that the broad sense heritability for chlorophyll was 0.82. The genetic advance and genetic gain were observed to be 6.46 and 14.66 respectively. The value of genetic advance was the highest when compared with other values. The value for the broad sense heritability was observed to be the lowest (0.72) for this character when compared with other traits. The genetic advance and genetic gain were observed to be 1.23 and 62.32 respectively. Broad-sense heritability value was observed to be (0.81) for this character. The genetic advance was estimated to be 0.12 and genetic gain was observed to be 105.94, which was found to be the highest among all the traits and for genetic advance it was observed to be the least. The value for the broad sense heritability was observed to be (0.81) for this trait. The genetic advance and genetic gain were observed to be 1.45 and 86.26 respectively. For the broad sense heritability, the highest value (0.92) was observed among all the traits. The genetic advance and genetic gain observed for these traits were 3.65 and 10.91 respectively.

The broad sense heritability (0.72) was found to be the least among all the characters studied. The genetic advance and genetic gain also showed the least value 1.23 and 1.52 respectively.

Correlation study of the morphological and physiological characters of seedlings Correlation analysis of the morphological and physiological trait of progenies from the selected plus trees is given in Table 6. It was observed that the height had significant (p<0.01) positive relationships with all the growth traits of the seedling such as girth (0.61), absolute growth rate (0.74) and biovolume (0.9). The relation with the physiological parameters like photosynthesis (0.55), stomatal conductance (0.67), transpiration (0.63) and relative water content (0.61) of the seedlings were also positive (p<0.01). However, it was observed that height had a negative relationship with leaf temperature and positive relationship with the chlorophyll content, but the relation was not significant. Girth of the seedlings had positive significant (p<0.01) correlation with the biovolume (0.70) and stomatal conductance (0.43) of the leaves of seedlings. It was not related to absolute growth rate, chlorophyll content, photosynthesis, transpiration, relative water content. Absolute growth rate (AGR) was found to be positively (p<0.01) related to biovolume (0.52), transpiration (0.40) and relative water content (0.41). The relation with photosynthesis and stomatal conductance was not significant. Biovolume of the seedlings was significantly related with all the morphological and physiological parameters studied. It showed a positive relation with chlorophyll content (0.46), photosynthesis (0.61), stomatal conductance (0.70), transpiration (0.40) and relative water content (0.41). It showed a significant (p<0.05) negative relation with leaf temperature. The chlorophyll content of the leaves was significantly related with all the morphological and physiological parameters studied. It was positively related to photosynthesis (0.46), stomatal conductance (0.71), transpiration (0.65) and relative water content (0.61). The chlorophyll content was negatively related (p<0.01) to the leaf temperature (0.51). The relation of photosynthesis with stomatal conductance (0.88), transpiration (0.83) and relative water content (0.61) was positive and significant at 0.01 percent level, however a significantly (p <0.01) negative correlation was observed with leaf temperature (0.85). Highly positive correlation (p<0.01) was observed for stomatal conductance with transpiration (0.95) and relative water content (0.64), while it was negatively correlated with leaf temperature (0.85). Transpiration had significant positive correlation with the relative water content (0.70) and negative correlation with leaf temperature (0.87). Highly negative correlation (p<0.01) was observed with relative water content of the leaves (0.54). The leaf temperature had a significant negative correlation with all the growth and physiological traits of the seedlings.

Discussion

In our study, significant differences among the progenies of the twenty five selected plus trees were observed for various morphological traits such as shoot height, collar diameter, number of leaves, absolute growth rate (AGR) and biovolume at the end of the experiment (Table 2). It was observed that among the progenies studied, the performance of the progenies from the two plus trees FCV-MD-03 and FCV-MD-04 selected from the Tholpetty Forest showed highest growth. Earlier research done in similar lines tended to emphasize the existence of variability in growth parameters due to different genotypes and their variations with the differences in soil and climatic conditions at the nursery stage. In a study done to observe the genetic variations among the half-sib families of selected plus trees in *Melia dubia*, it was observed that among the progeny of 20 trees studied three families exhibited superiority for different growth parameters when compared to other trees (Kumar *et al*. 2013) [30]. Similarly, this type of differences and the ability of a few seed sources to excel, among different half sib families and provenances was reported for *Lagerstromia* spp. (Jamaludheen *et al*. 1995) [23]. Superiority of growth for some provenances was reported in *Acacia nilotica* (Ginwal *et al*. 1995) in *Acacia catechu* (Mohapatra, 1996) [42] in *Prosopis cineraria* (Manga and Sen, 1998) in *Melia azedarach* (Jain & Dhar, 2008; Thakur & Thakur, 2015) [22, 60], in *Acacia catechu* (Gera & Gera, 2006), in *Ailanthus excelsa* (Daneva *et al*. 2018) [11], thus supporting our current results. Thus, it can be concluded that all living organisms possess a sizable quantity of natural variability that is present for various characters in most populations (Thakur & Thakur, 2015) [60]. In species with widespread natural distribution, variations are expected between populations due to the differences in the genetic and environmental condition in which the plant is growing. Even though the seedlings from seeds of all the twenty five plus trees were raised under the same environmental conditions, variations were observed between the progenies with respect to some of the traits related to the growth characteristics of progenies. This shows that the differences observed in the growth traits are due to the difference in the genetic ability of individual progenies. The results of the assessment of progenies of the plus trees can be used to evaluate the progenies among themselves. It also gives a good amount of information about the ability of the parents to pass on the characters to its progeny, for which selection was originally done.

The information gathered from this study can be used for selecting the exceptionally good parents, which can be used repeatedly in future for the establishment of a seed orchard or can be used for hybridization. Usually, the causes of variation could be assessed by partitioning the total variability into phenotypic and genotypic variability. After partitioning the part of the variation that is heritable that can be used for future programmes. In our study, the values of phenotypic coefficient of variation (Table 4) ranged from 12.62 per cent for height to 24.53 per cent for biovolume, whereas the genotypic coefficient of variation ranged from 10.18 per cent for collar diameter to 22.53 per cent for biovolume. The phenotypic and genotypic coefficient of variation in the current study indicated that biovolume registered the highest phenotypic and genotypic coefficient of variation compared to other parameters. This was followed by the absolute growth rate, the number of leaves, collar girth and height. Overall, the value of genotypic coefficient of variation was lower in magnitude when compared to that of the phenotypic coefficient of variation (Table 4). The above results indicate, there exists an environmental effect on these characters. It was reported earlier also in a similar study done in neem (Amit *et al*. 2018). In Melia dubia, volume index showed high PCV and GCV value, followed by height and collar diameter (Kumar *et al*. 2013) [30]. High GCV for the vigour index was earlier reported in teak (Prasad, 1996; Parthiban, 2001) and low GCV for height in Eucalyptus tereticornis (Sundararaju *et al*., 1995). In Bambusa pallida, low GCV and PCV was reported for height and collar diameter (Singh and Beniwal, 1993). In the current study also, height and collar diameter recorded lower GCV and PCV compared to other parameters (Table 4). The genotypic and phenotypic coefficient of variation recorded in this experiment, provides evidence that there exists adequate genotypic variation. For further improvement of the species these variabilities can be exploited. Similar results and conclusions were observed in Eucalyptus tereticornis (Kumar *et al*. 2010) [29]. Heritability indicates the total amount to which a character is influenced by heredity when compared to the environment. The values of the heritability for different characters showed moderate to high heritability for height (0.91), collar diameter (0.53), number of leaves (0.65), absolute growth rate (0.83) and biovolume (0.84). For all the traits it was observed that the heritability in the broad sense were higher than 50 per cent (Table 4). The high values of heritability help the breeder in the selection programme. Johnson *et al*. (1955) [25] suggested that for selecting the best individuals from a given population the heritability values and genetic advance are of great help, as from this the resultant effect can be predicted. Heritability (broad sense) is usually due to non-additive gene action (dominance and epistasis), so this value to be more realistic has to be accompanied with high genetic gain. In our study, it was observed that the genetic advance (in per cent of the mean) was maximum for biovolume (792.58), followed by plant height (36.53) and the number of leaves (4.24) (Table 4). High heritability, coupled with moderate to high genetic advance (% mean) obtained for these characters indicated that the higher values are due to additive gene effects. This shows a broad scope for the genetic improvement in the species, as it gives an indication on the proportionate role of heredity and the environment at the time of expression of various traits (Dorman, 1976) [14]. Similar results were obtained in *Melia dubia*, where it was observed that the values of PCV were higher for volume index, followed by height and basal diameter (Kumar *et al*. 2013) [30]. High heritability together with moderate to high genetic advance for different growth traits have earlier been reported by Arun (1996) [3] in *Tectona grandis*; Solanki *et al*. (1984) in *Prosopis cineraria*; Gera *et al*. (2001) in *Dalbergia sissoo* and Dhillon *et al*. (2003) [13] in *Azadirachta indica*. In *Eucalyptus globulus* during the field study of the eight sub- races, it was observed that the heritability for DBH was low (Apiolaza *et al*. 2005) [2]. Similarly, in *Eucalyptus globulus* and *E. nitens*, it was observed that for different genetic parameters the heritability was low to moderate. It was observed again in E. grandis that the heritability for height and tree volume was low to moderate (Raymond, 2002) [50]. In another experiment, it was also observed that the heritability varied with changing environment and age (Devagirigm *et al*. 1997) [12].

Physiological variation of the progenies and correlation with the growth characters

The physiological traits such as transpiration and photosynthetic rate, chlorophyll content, stomatal conductance, relative water and content leaf temperature of the seedlings were determined (Table 3). The highest value for chlorophyll content, photosynthetic rate, relative water content was observed for the progenies from the plus trees FCV-MD-03 and FCV-MD-04. The lowest value for the photosynthesis, stomatal conductance, transpiration, leaf temperature was observed for the seedlings from plus trees FCV-MD-11 and FCV-MD-17 for all the characters (Table 3). The PCV for the physiological traits (Table 5) was found to be highest for the stomatal conductance (64.28) followed by transpiration rate (51.87), photosynthetic rate (41.74), chlorophyll content (8.71), leaf temperature (5.77) and relative water content (1.02). It was observed that the GCV for the traits varied from 57.5 for stomatal conductance to 0.87 for RWC, further the values of PCV when compared to that of GCV for the similar characters were less. Similar results were observed for all the characters (Table 5). The values of heritability varied from 0.92 (leaf temperature), 0.82 (chlorophyll content), 0.81 (transpiration), 0.8 (stomatal conductance) to 0.72 (photosynthesis and relative water content). The genetic gain was maximum for stomatal conductance (105.94), followed by transpiration (86.26), photosynthesis (62.32), chlorophyll content (14.66), leaf temperature (10.91) and the least for relative water content (1.52). Photosynthesis is the fundamental processes that provide the organic blocks that contribute largely to the plant development and growth, among the various life processes that control plant growth (Rapparini & Penuelas, 2014) [48]. It largely influences the plant growth and yield (Yamori *et al*. 2016). Both the environmental factors and plant genetic characteristics influence the rate of photosynthesis. Thus, it can be concluded that photosynthetic activity is complex and interaction between plant genetic and environmental factors is involved in it. Stomatal conductance measures the degree of stomatal opening, which can be further used as a pointer to the water status in plants (Carmen *et al*. 2013) [17]. It is an important factor in energy, CO_2 and water cycling between plants and the atmosphere. It is also vital for both prevention of desiccation and CO_2 acquisition (Medici *et al*. 2007) [40]. Studies have shown that plants respond to water deficit very early with closure of stomata, which leads to a limitation in carbon uptake by the leaves. This can in turn result in the reduction of photosynthetic rate of the plants (Chaves, 1991 & Conic, 2000) [8, 10]. Studies show that the higher stomatal conductance of plants has been associated with higher leaf water content (Auge *et al*. 2015) [4]. The efficiency of net photosynthesis and stomatal conductance are often related to each other (Salisbury & Ross, 1992) [52]. Studies have also shown that the net photosynthetic rates and opening of stomata are indirectly related to each other (Bunce, 1988) [6]. Hence, variations in stomatal conductance can result in the change in photosynthetic rates (Meng & Arp, 1992). Plants respond to water deficit, which is controlled by the stomata, which has been identified much earlier. The closure of the stomata leads to a limitation in carbon uptake by the leaves (Chaves, 1991) [8]. It is also reported that there are many determinants of plant productivity. The most important among them is the changes that causes differences in net photosynthesis, stomatal density and size (Luukkanen & Kozlowski, 1972; Pallardy & Kozlowski, 1979; Blake & Bevilacqua, 1995; Wang *et al*. 1995) [35, 44, 5, 62].

Earlier the studies were mainly focused on ecophysiological aspects on photosynthesis in forest trees such as the effects of stress on photosynthetic physiology, and the photosynthetic responses to light intensity (Zhang *et al*. 2002) [64] and CO_2 concentration (Su *et al*. 2003) [56]. Our study focused on measuring the rate of photosynthesis and chlorophyll parameters, we also attempted at correlating the physiological characters of the seedlings with its growth (Table 6). The results showed significant variation in net photosynthesis rate and the value ranged from 0.29 to 3.56 µmol m-2 s^{-1} for different progeny of the plus trees. Similarly, the values observed for the stomatal conductance varied from 0.01 to 0.27 s cm^{-1}. Significant variations between the provenance for the physiological traits such as net photosynthesis, stomatal density, stomatal conductance, leaf area, whole-plant dry weight, total guard cell length was observed for neem seedlings (Kundu & Tigerstedt, 1997) [32]. Similar findings have been reported by Mebrahtu and Hanover (1991) [39] for blacklocust (*Robinia pseudoacacia* L.) and for black spruce (*Picea mariana* Mill.) by Johnsen and Major (1995) [24]. In a study where a multispecies meta-analysis was done from the data sets of 17 published studies, the values for the net photosynthetic rate was observed to vary from 0.8 to 30.6 µmol m^{-2} s^{-1} and value of stomatal conductance, from 0.01 to 0.62 s cm^{-1} (Gagoj, *et al*. 2016) [16]. In a study done in *Quercus serrata* to investigate the dependence of the concentration of chlorophyll on stomatal conductance, it was observed that as the chlorophyll concentration decreased a corresponding decrease in stomatal conductance was also observed (Matsumoto *et al*. 2005) [37]. In our study, the higher chlorophyll content and photosynthetic rate might have led to the accumulation of photosynthates in the progeny of plus tree FCV-MD-03 and FCV-MD-04, resulting in its above-average growth. The values for the broad sense heritability were observed to be greater than 50 per cent for most of the traits (Table 5). The above results were generally consistent with the studies done in different clones of *Tectona grandis*, where high heritability was observed for the photosynthetic rate, chlorophyll content and stomatal conductance. High heritability and genetic advance were observed for *Populus niagra* (Chuyg, 2010) [9]; in *Dalbergia sissoo* (Sharma & Bakshi, 2014) [54]; in *Populus trichocarpa* (Mckown *et al*. 2014) [38]. In this study it was generally observed that the progenies of the selected plus trees had high variation and heritability (H^2) for most of the growth and physiological traits (Table 5). The results of our experiment showed that seedlings from different plus trees have different photosynthetic rates. The seedlings of plus trees FCV-MD-03 and FCV-MD-04 had high photosynthetic rates. It was observed that net photosynthetic rate showed a significantly positive correlation with seedling height, individual volume, which was an interesting finding of this study (Table 3). The results indicate that the seedlings of plus trees with high photosynthetic rate result in fast-growing plants. The above result was generally consistent with the studies done in different clones of *Tectona grandis*, where high heritability was observed for the photosynthetic rate, chlorophyll content and stomatal conductance for some of the clones studied. These traits were positively correlated with seedling height and volume of the clones. Their study further revealed that this parameter can be used as one of the major tools for the breeding and improvement programme of the tree species (Huang, 2019) [21]. In Populus nigra, it was observed that species originating in Serbia had a high correlation with the growth, the gas exchange and also with chlorophyll fluorescence parameters. The result showed that this germplasm can be used for future breeding programmes as they were found to be highly correlated and having high photosynthetic efficiency (Chuyg *et al*. 2010) [9]. High heritability and genetic advance for the above-mentioned traits were observed for *Populus niagra* (Chuyg *et al*. 2010) [9]; in *Dalbergia sissoo* (Sharma & Bakshi, 2014) [54]; in *Populus trichocarpa* (Mckown *et al*. 2014) [38]. Therefore, from our study and the results of other research, it can be concluded that the net photosynthetic rate showed variation between the genotypes. Thus, this can be used as a parameter for improving the efficiency of melia breeding. The results shall provide as a means of evaluation of melia germplasm, and the knowledge can be used for the introduction and improvement of melia resources in improvement programs.

Conclusion

Selecting parents and evaluating progenies is a very precarious step in any breeding programme. The present study shows that there were differences among progenies of the selected plus trees for the morphological characters. It was observed that the progenies from the plus tree FCV-MD-03 and FCV-MD-04 selected from the Tholpetty Forest showed the highest growth for all the observed characters viz. shoot height, collar diameter, number of leaves, absolute growth rate (AGR) and biovolume. The lowest value for the shoot height and absolute growth rate (AGR) was observed for plus tree (FCV-MD-09) from Attappady region. The least value for biovolume was observed for the progenies of plus tree FCV-MD-17 from Chinnar. Variation among the progeny with respect to the chlorophyll content, photosynthetic rate, stomatal conductance, transpiration rate and of the relative water content (RWC) of the leaves were also observed. The progeny from the plus tree FCV-MD-03 and FCV-MD-04 showed the highest values for the physiological characters. It was also observed that the estimates of the heritability for the various morphological and physiological characters showed moderate to high heritability. The high values of heritability help the breeder in the selection programme. The heritability estimates together with genetic advance are usually more helpful in selecting the best individuals. The study also showed that net photosynthetic rate had a significantly positive correlation with seedling height and individual volume, which was an interesting finding. The results indicated that the seedlings of plus trees with high photosynthetic rate resulted in fast-growing plants. All this shows that there is a scope for using the net photosynthetic rate as a parameter for selection as it has high practical significance and can be effectively used for improving the efficiency of melia breeding. The results indicate that some of the germplasms are suitable for breeding of melia especially for the characters such as high photosynthetic efficiency. Our study indicated the possibility of choosing the best plus tree for a breeding program based on morpho physiological characters of the seedlings.

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Conflicts of Interest

The authors have no conflicts of interest to declare that are relevant to the content of this article.

Table 1: Details of the twenty five selected plus of *Melia dubia* trees from different localities

Sl. No.	Accession No.	Location	Locality	Range/WLS
1.	FCV-MD-01	11°54'16.9" 75.59°59.77"	Thirunelly	Begur
2.	FCV-MD-02	11°54'37.68" 76°00'02.40"		
3.	FCV-MD-03	11°47'46.90" 76°05'04.10"	Tholpetty	Tholpetty WLS
4.	FCV-MD-04	11°53'13.20" 76°04'34.70"		
5.	FCV-MD-05	11°52'53.10" 76°04'39.20"	Dasanakara	Chedelthu
6.	FCV-MD-06	11°25'32.10" 76°06'02.30"	Neykavala	Chedelthu
7.	FCV-MD-07	10°27'02.10" 76°12'24.30"	Dhoni	Olavakode
8.	FCV-MD-08	10°31'00.92" 76°37'00.28"	Poothundy	Nelliampathy
9.	FCV-MD-09	11°05'30.50" 76°43'23.50"	Attappad	Agali
10.	FCV-MD-10	10°31'15.20" 76°36'18.70"	Thiruvazhiyadu	Nelliampathy
11.	FCV-MD-11	10°31'01.90" 76°36'30.40"	Walayar	Walayar
12.	FCV-MD-12	10°51'35.90" 76°37'15.70"		
13.	FCV-MD-13	10°51'33.50" 76°37'27.10"	Parambikulam	Karimala
14.	FCV-MD-14	10°22'56.90" 76°45'45.01"		
15.	FCV-MD-15	10°26'41.3" 76°49'35.90"		Sungam
16.	FCV-MD-16	10°24'40.40" 76°49'35.30"		
17.	FCV-MD-17	10°21'16.20" 77°11'32.20"	Chinnar	Chinnar WLS
18.	FCV-MD-18	10°21'16.20" 77°11'29.60"		
19.	FCV-MD-19	10°21'13.50" 77°11'38.20"		
20.	FCV-MD-20	10°31'56.20" 76°22'26.20"	Peechi Thrissur	Pattikkad Peechi Vazhani WLS
21.	FCV-MD-21	10°29'01.00" 76°22'00.01"		
22.	FCV-MD-22	10°40'46.10" 76°18'10.30"	Akamala	Machad
23.	FCV-MD-23	08°50'36.80" 77°02'53.2"	Kulathupuzha	Kulathupuzha
24.	FCV-MD-24	08°51'22.3" 77°08'48.60"	Aryankavu	Aryankavu
25.	FCV-MD-25	08°55'55.40" 77°08'38.70"		Thenmala

Table 2: Physiological parameters of *Melia dubia* progenies from different plus trees at 150 DAT

Accession No.	Height (cm)	Collar dimeter (cm)	No of leaves	Absolute growth rate (cm day-1)	Bio-volume
FCV-MD-01	164.7	1.26*	24	2.51	2062.68
FCV-MD-02	164.1	1.37*	26	2.49	2233.03
FCV-MD-03	199.0*	1.54*	26	3.23*	3048.57*
FCV-MD-04	198.7*	1.61*	31	3.10*	3175.22*
FCV-MD-05	163.5	1.18	26	2.31	1956.54
FCV-MD-06	162.5	1.29*	27	2.68	2109.35
FCV-MD-07	165.1	1.31*	28	2.45	2166.53
FCV-MD-08	163.3	1.29	22	2.51	2219.37
FCV-MD-09	112.2	1.20	23	1.39	1355.48
FCV-MD-10	120.6	1.04	20	2.20	1599.09
FCV-MD-11	182.9*	0.98	21	2.34	1499.89
FCV-MD-12	181.3*	0.93	19	2.80	1581.83

FCV-MD-13	160.6	1.11	22	1.75	1594.46
FCV-MD-14	141.5	1.10	23	1.87	1591.94
FCV-MD-15	141.3	1.11	21	1.87	1589.34
FCV-MD-16	148.9	1.42*	26	2.36	2145.34
FCV-MD-17	128.1	1.08	26	1.94	1330.50
FCV-MD-18	139.7	1.12	23	2.18	1606.77
FCV-MD-19	140.3	1.28	23	2.39	1875.23
FCV-MD-20	147.4	1.08	21	2.38	1651.98
FCV-MD-21	158.7	1.06	22	2.38	1581.13
FCV-MD-22	162.1	1.20	23	2.46	1912.64
FCV-MD-23	155.2	1.19	17	2.46	1773.99
FCV-MD-24	153.0	1.13	19	2.21	1692.14
FCV-MD-25	146.8	1.11	24	1.59	1500.83
Mean	157.20	1.19	23.34	2.31	1874.16
SEd	24.00	0.21	4.07	0.56	524.87
CD (0.05)	17.03	0.32	5.23	0.66	527.34
CD (0.01)	22.71	0.43	6.98	0.5	703.04

FCV-MD-01-25 = *Melia dubia* progenies, DAT = Date after transplanting, SED = standard error of differences, CD = critical differences

Table 3: Physiological parameters of *Melia dubia* progenies from different plus trees at 150 DAT

	Chlorophyll content (mg g^{-1})	**Photosynthetic rate (µmol m-2 s^{-1})**	**Stomatal Conductance (s cm^{-1})**	**Transpiration rate (µmol m-2 s^{-1})**	**Leaf temperature (ºC)**	**Relative water content (%)**
FCV-MD-01	49.17	2.04	0.12	1.80	32.67	82
FCV-MD-02	44.67	2.64	0.21	2.79	31.70	81
FCV-MD-03	51.6*	2.80	0.27*	3.49*	31.98	89 *
FCV-MD-04	49.40	3.56*	0.23	2.96	31.81	88*
FCV-MD-05	48.00	2.08	0.14	2.25	33.00	81
FCV-MD-06	41.40	0.78	0.06	1.11	34.29	81
FCV-MD-07	43.10	0.71	0.03	0.82	35.04	84
FCV-MD-08	46.37	0.98	0.04	0.89	35.15	76
FCV-MD-09	48.57	0.86	0.02	0.54	35.60	73
FCV-MD-10	39.73	0.79	0.02	0.42	36.77	79
FCV-MD-11	33.30	0.81	0.01	0.33	37.10	74
FCV-MD-12	40.87	0.84	0.01	0.33	37.03	83
FCV-MD-13	35.70	0.29	0.02	0.35	36.69	75
FCV-MD-14	49.40	2.58	0.11	1.72	31.77	82
FCV-MD-15	39.00	2.52	0.14	1.91	31.15	81
FCV-MD-16	49.83	1.92	0.14	2.05	32.08	82
FCV-MD-17	43.90	1.09	0.11	2.07	33.27	80
FCV-MD-18	41.00	1.70	0.13	1.81	32.14	78
FCV-MD-19	46.43	1.19	0.09	1.59	32.42	80
FCV-MD-20	48.10	2.08	0.14	2.26	31.87	82
FCV-MD-21	48.60	1.46	0.12	2.24	32.44	84
FCV-MD-22	47.73	1.42	0.13	2.34	31.77	86
FCV-MD-23	38.20	2.27	0.18	1.86	31.82	79
FCV-MD-24	39.27	2.33	0.10	2.11	32.89	82
FCV-MD-25	37.60	1.98	0.10	1.94	33.82	82
Mean	44.04	1.67	0.11	1.68	33.45	81
SEd	3.01	0.91	0.08	0.87	2.05	1.24
CD (0.05)	2.16	1.23	0.08	1.08	1.57	3.24
CD (0.01)	2.56	1.64	0.12	1.44	2.09	4.12

FCV-MD-01-25 = *Meliadubia* progenies, DAT = Date after transplanting, SED = standard error of differences, CD = critical differences

Table 4: Estimated genetic parameters of morphometrical traits of *Melia dubia* plus trees

	H2	**PCV**	**GCV**	**ECV**	**Genetic advance**	**Genetic Gain**
Height	0.91	12.62	12.01	3.87	36.53	23.55
Collar diameter	0.53	13.98	10.18	9.58	0.18	15.26
No of leaves	0.65	13.45	10.88	7.9	4.24	18.15
AGR	0.83	18.28	16.65	7.54	0.72	31.25
Biovolume	0.84	24.53	22.44	9.91	792.58	42.29

Table 5: Estimated genetic parameters of physiological traits of *Melia dubia*

	H2	PCV	GCV	ECV	Genetic advance	Genetic Gain
Chlorophyll	0.82	8.71	7.87	3.73	6.46	14.66
Photosynthetic	0.72	41.74	35.53	21.90	1.23	62.32
Stomatal conductance	0.80	64.28	57.50	28.75	0.12	105.94
Transpiration	0.81	51.87	46.60	22.77	1.45	86.26
Leaf temperature	0.92	5.77	5.53	1.65	3.65	10.91
RWC	0.72	1.02	0.87	0.54	1.23	1.52

Table 6: Correlation of various morphological and physiological characters of the seedlings of *Melia dubia*

	Height (m)	Girth (cm)	Absolute Growth Rate (cm day^{-1})	Biovolume	Chlorophyll (mg/gm)	Photosynthesis (µmol m^{-2} s^{-1})	Stomatal conductance (s cm^{-1})	Transpiration (µmol CO_2 m^{-2} s^{-1})	Leaf temperature (ºC)	RWC (%)
Height (m)	1									
Girth (cm)	**	1								
Absolute Growth Rate (cm day^{-1})	.741**	.359	1							
Biovolume	.900**	.702**	.516**	1						
Chlorophyll (mg/gm)	.286	.344	-.014	.466*	1					
Photosynthesis (µmol m^{-2} s^{-1})	.551**	.261	.279	.608**	.455*	1				
Stomatal conductance (s cm^{-1})	.660**	.428*	.383	.704**	.478*	.876**	1			
Transpiration (µmol CO_2 m^{-2} s^{-1})	.633**	.390	.403*	.645**	.541**	.833**	.952**	1		
Leaf temperature (º C)	-.327	-.114	-.206	-.402*	-.506**	-.828**	-.845**	-.873**	1	
RWC (%)	.603**	.329	.410*	.600**	.494*	.608**	.640**	.704**	-.543**	1

**Significant at the 0.01 level.
*Significant at the 0.05 level.

References

1. Allard RW. Principles of Plant Breeding. John Wiley and Sons Inc., New York; c1960. p. 264.
2. Apiolaza LA, Raymond CA, Yeo BJ. Genetic variation of physical and chemical wood properties of *Eucalyptus globulus*. Silvae genetica. 2005;42(1):9-15.
3. Arun KC. Variability studies in teak (*Tectona grandis* Linn. F.). M.Sc. Thesis, Tamil Nadu Agricultural University, Coimbatore; c1996.
4. Auge RM. Hdtoler & Saxtonam, Arbuscular mycorrhizal symbiosis alters stomatal conductance of host plants more under drought than under amply watered conditions: a meta-analysis. Mycorrhiza. 2015;25:13-24.
5. Blake TJ, Bevilacqua E. Early selection of *Eucalyptus grandis* clones in central Brazil. Journal of Tropical Forest Science. 1995;8:33-43.
6. Bunce JA. Effects of boundary layer conductance on sub stomatal pressures of carbon dioxide. Plant Cell Environment. 1988;11:205-208.
7. Burton GW, De-Vane DW. Estimating heritability in fesue (*Festuca arundinacea*) from replicated clonal material. Agronomy Journal. 1953;45:478-481.
8. Chaves MM. Effects of water deficits on carbon assimilation. Journal of Experimental Botany. 1991;42:1-16.
9. Chuyg XH SU, Huang QJ, Zhang XH. Relationships between photosynthetic characteristics and growth traits in gene resources of *Populus nigra*. Scientia Silvae Sinica. 2010;46:77-83.
10. Conic G, Massacci A. Leaf photosynthesis under drought stress. In: Baker NR. (ed.), Photosynthesis and the environment. Kluwer Academic Publishers, New York; c2000. p. 346-366.
11. Daneva V, Dhillon RS, Johar V. Plus, tree selection and progeny testing of superior candidate plus trees (CPTs) of *Ailanthus excelsa*. Journal of Pharmacology and Phytochemistry. 2018;7(2):543-545.
12. Devagirigm Singh JM, Chand R, Srivastava LJ. Genetic variability in *Heracleum candicans*. Indian Journal of Genetics. 1997;57(3):280-286.
13. Dhillon RS, Bisla SS, Arya S, Hooda MS. Genetic variation, heritability and correlation for growth parameters in *Azadirachta indica* A. Juss. Annals of Forestry. 2003;11(2):215-221.
14. Dorman KW. The genetics and breeding of Southern Pines. U.S. Dept. of Agril. For. Serv. Agric. Handbook No. 471; c1976. p. 407.
15. Duncan DB. Multiple range and multiple F tests. Biometrics. 1955;11:1-41. https://doi.org/10.2307/3001478
16. Gagoj, Menezes Daloso De D, Figueroa CM, Flexas J, Fernie, Znikoloski. Relationships of leaf net photosynthesis, stomatal conductance, and mesophyll conductance to primary metabolism: a multispecies meta-analysis approach. Plant Physiology. 2016;171(1):265-279.
17. Gimenez, Carmen, Gallardo M, Thompson RB. Plant-Water Relations; c2013. 10.1016/B978-0-12-409548-9.05257-X.
18. Ginwal, Harish, Mandal A. Variation in Growth Performance of *Acacia nilotica* Willd. ex Del. Provenances of Wide Geographical Origin: Six Year Results. Silvae Genetica; c2004. p. 53. 10.1515/sg-2004-0049.
19. Govindachari TR. Chemical and biological investigation on *Azadirachta indica* (Neem tree). Current Science. 1992;63:117-122.
20. Hatchell GE. Production of bare root seedlings. In:

Should, E. (ed.) Proceedings of third Biennial Southern Silviculture Research Conference. 7-9 November 1984. Atlanta; c1985. p. 395-402.

21. Huang G, Liang K, Zhou Z, Yang G, Muralidharan EM. Variation in photosynthetic traits and correlation with growth in Teak (*Tectona grandis* Linn.) Clones. Forest. 2019;10(1):44.
22. Jain A, Dhar P. Evaluation of provenances for seedling growth and biomass attributes in Azadirachta indica A. Juss. Indian Forester; c2008. p. 907-915.
23. Jamaludheen V, Gopikumar K, Sudhakara K. Variability studies in *Lagerstroemia speciosa*. Indian Foresters. 1995;121(2):137-141.
24. Johnsenkh, Major JE. Gas exchange of 20-year-old black spruce families displaying a genotype environment interaction in growth rate. Canadian Journal of Forestry Research. 1995;25:430-439.
25. Johnson HW, Robinson HF, Comstock RE. Estimation of genetic and environmental variability in Soya beans. Agronomy Journal. 1955;47:314-318.
26. Kiritkar KR, Basu BD. Indian Medicinal Plants. In: Blatter E, Caicus JF and Mhaskar KS. (eds.), International Book Distributors, Dehradun. 1999;1:545-546.
27. Koul O, Jain MP, Sharma VK. Growth Inhibitory and Antifeedant Activity of Extracts from *Melia dubia* to *Spodoptera litura* and *Helicoverpa armigera* larvae. Indian Journal of Experimental Biology. 2000;38(1):63-68.
28. Kumar A, Shrivastava P, Sharma S, Dobhal S, Rana A, Kumar R. Development of High Yielding Varieties of *Melia dubia* Cav. (Syn. *M. composita* Benth.). Indian Forester. 2017;143(11):1203-1206.
29. Kumar A, Luna RK, Parveen Kumar V. Variability in growth characteristics for different genotypes of *Eucalyptus tereticornis* (SM), Journal of Forestry Research. 2010;21(4):487-491.
30. Kumar P, Parthiban KT, Saravanan V. Genetic variations among open pollinated families of selected better trees in *Melia dubia*. Res. J Recent Sci.; c2013. p. 2502. ISSN, 2277.
31. Kumar VGS, Aishwarya R. Development of Proliferation and Acclimatization of *Melia dubia*-Australian Teak Variety through Micropropagation. International Journal of Innovative Research in Science, Engineering and Technology. 2017;6(1):1226-1236
32. Kundu SK, Tigerstedt PMR. Geographic variation in seed and seedling traits of Neem (*Azadirachta indica*) among 10 populations studied in growth chamber. Silvae Genetica. 1997;46(2-3):129-137.
33. Leela G, Jdayana, Monisha S, Irudaya I, Anitha A, Rosaline JV. Studies on phytochemical, nutritional analysis and screening of *in vitro* biological activities of *Melia dubia* leaf extract. International Journal of Innovative Research in Science, Engineering and Technology. 2016;7(8):56-68.
34. Lush JL. Intensive correlation and regression of off springs of damsasa method of eliminating heritability characters. Proc. Am. Soc. Anin. Prod. 1940;33:293-301.
35. Luukkanen O, Kozlowski TT. Gas exchange in six Populus clones. Silvae Genetica. 1972;21:220-229.
36. Manga V, David S. Genetic parameters for seed traits in *Prosopis cineraria*. Indian Journal of Forestry. 1996;19:148-151.
37. Matsumoto K, Ohta T, Tanaka T. Dependence of stomatal conductance on leaf chlorophyll concentration and meteorological variables. Agricultural and Forest Meteorology; c2005. p. 132. 10.1016/j.agrformet.2005.07.001.
38. Mckown AD, Guy RD, Klapste J, Geraldes A, Friedmann, Cronk QC, *et al*. Geographical and environmental gradients shape phenotypic trait variation and genetic structure in *Populus trichocarpa*. New Phytologist. 2014;201(4):1263-1276.
39. Mebrahtut & Hanover JW. Leaf age effects on photosynthesis and stomatal conductance of black locust seedlings. Canadian Journal of Forestry Research. 1991;21(11):1616-1621.
40. Medici, Leonardo Oliveira *et al*. Stomatal conductance of maize under water and nitrogen deficits. Pesquisa Agropecuária Brasileira [online]. 2007;42(4):599-601. [Accessed 19 June 2021]. Available from: <https://doi.org/10.1590/S0100-204X2007000400020>.Epub 25 May 2007. ISSN 1678-3921.https://doi.org/10.1590/S0100-204 X20 0700400020.
41. Meng, Fan-Rui, Paul A. Net photosynthesis and stomatal conductance of red spruce twigs before and after twig detachment. Canadian Journal of Forest Research. 2011;23:716-721. 10.1139/x93-093.
42. Mohapatra KP. Variability studies for seedling traits in *Acacia catechu.* Willd. Under nursery conditions. M.Sc. Thesis, Dr. Y. S. Parmar University of Horticulture and Forestry, Nauni-Solan; c1996.
43. Nair NG. Distribution of Important Forest Tree Species in Kerala (Southern Circle). Research Report No. 75, Kerala Forest Research Institute, Peechi; c1991. p. 17.
44. Pallardy SG, Kozlowski TT. Frequency and length of stomata of 21 *Populus* clones. Canadian Journal of Forestry Research. 1979;57:2519-2523.
45. Panse VG, Sukhatme PV. Statistical Methods for Agricultural Workers. ICAR New, Delhi; c1961.
46. Parthibankt, Akilesh KB, Seenivasan R, Kamala K, Govinda RM. Integrating *Melia dubia* in agroforestry farms as an alternate pulpwood species. Asia Pacific Agroforstry Newsletter No. 34, Thammada Press Co. Ltd., Bangkok, Thailand; c2009. p. 3-4.
47. Prasad, Kulkarni HD. Techniques of propagation of forest trees. Tissue culture vs. Mist propagation. Vaniki Sandesh. 1988;11(4):10-15.
48. Rapparini F, Penuelas J. Mycorrhizal fungi to alleviate drought stress on plant growth. In: Use of Microbes for the Alleviation of Soil Stresses. Springer, New York. 2014;1:21-24.
49. Rawat S, Kumar AN, Annapurna D, Karaba NN, Joshi G. Genetic diversity of *melia dubia* using ISSR markers for natural populations and plantations. International Journal of Genetics. 2018;10(9):490-494.
50. Raymond CA. Genetics of Eucalyptus wood properties. Annals of Forest Science. 2002;59:525-531.
51. Saini V, Kinger HK, Middha A, Rathore GS. Study of anti-bacterial and anti-fungal activity of *Melia dubia* leaves. International Journal of Research in Ayurveda and Pharmacy. 2007;2(1):239-240.
52. Salisbury FB, Ross CW. Plant Physiology, 4th Edn. Wadsworth Publishing Company, Belmont, CA; c1992.

p. 682.
53. Saravanan V, Parthiban KT, Kumar P, Marimuthu P. Wood characterization studies on *Melia dubia* Cav. for pulp and paper industry at different age gradation. Research Journal of Recent Science. 2013;2:183-188.
54. Sharma, Arvind, Bakshi, Meena. Variability in Growth, Physiological, and Biochemical Characteristics among Various Clones of *Dalbergia sissoo* in a Clonal Seed Orchard. International Journal of Forestry Research; c2014. p. 1-9. 10.1155/2014/829368.
55. Solanki KR, Muthana KD, Jindal SK, Arora GD. 1984. Variability, heritability, and correlations for growth parameters in *Prosopis cineraria.* Journal of Tree Science. 2014;3:86-88.
56. Su PX, Zhang LX, MW DU, YR BI, Zhao AF, Liu XM. Photosynthetic character and water use efficiency of different leaf shapes of *Populus euphratica* and their response to CO_2 enrichment. Acta Ecologica Sinica. 2003;27:34-40.
57. Subasini HD, Sekar S, Shri L, Devi VR. Biodegradation of pesticidal residue using traditional plants with medicinal properties and Trichoderma. Journal of Environmental Toxicology. 2007;1(3):124-130.
58. Suresh T, Devakumar AS. 2017. Morphological characterization of *Melia dubia* seeds: implications to germination. Mysore Journal of Agricultural Sciences. 2007;51(3):721-735
59. Susheela T, Balaravi P, Theophilus J, Reddy TN, Reddy PUM. Evaluation of hypoglycaemic and antidiabetic effect of *Melia dubia* CAV fruits in mice. Current Science. 2008;94(9):1191-1195.
60. Thakur IK, Thakur S. Variability, Heritability, Genetic Advance and correlation in growth characteristics of Melia Azedarach. Indian Forester. 2015;141(33):247-253.
61. Vijayanp, Raghu C, Ashok G, Dhanaraj SA, Suresh B. Antiviral activity of medicinal plants of Nilgiris. Indian Journal of Medical Research. 2004;120:24-29.
62. Wang T, Hagvist R, Tigerstedt PMA. The relationships between yield and carbon fixation in selected hybrid families after crossing selfed lines of *Betula pendula* Roth. Frontiers in Genetics. 1995;2:77-86.
63. White PR. The cultivation of animal and plant cells. Ronald Press, New York; c1963. p. 1-239.
64. Zhang WX, Wu JS, Cao FL. Influence of photosynthetically active radiation on photosynthesis and photochemistry efficiency in leaves of Ginkgo. J Nanjing For. Univ. (Nat. Sci. Ed.). 2002;26:5-9.