Received: 19 May 2021 | Revised: 06 Jun 2021 | Accepted: 28 Jun 2021

Electronic Journal of Plant Breeding

Research Article

Variability and plus tree selection in *Swietenia macrophylla* from Kerala, South India

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Abstract
Big leaf mahogany (*Swietenia macrophylla*, King) is a valuable Neotropic timber species. It is the first extensively traded timber species to be listed in Appendix II of the CITES in 2002. The tree was introduced to India in 1795 and Kerala in 1872. The present study aimed at selecting plus trees of *Swietenia macrophylla* and evaluating their genetic variability. Forty-five plus trees were selected from 593 candidate trees spread over fifteen locations in Kerala based on baseline regression of trunk volume to crown volume, followed by scoring for qualitative characters. The clean bole height, GBH, crown width, crown volume and wood density of CPTs ranged from 6 to 13.4 m, 0.75 to 2.00 m, 8 to 15 m, 7 to 16 m and 21 to 23 mm, respectively. The plus trees were grouped into five clusters based on their quantitative and qualitative characters. Clustering was independent of the geographical location indicating a lack of development of any land races in the species.

Key words: *Swietenia macrophylla*, Mahogony, Plus tree selection, CPT, Genetic variability

INTRODUCTION

Honduras or big leaf mahogany (*Swietenia macrophylla* King, Meliaceae) is a valuable neotropical timber species from southern Mexico to the upper Amazon and its tributaries in Peru, Bolivia and Brazil (Cespedes *et al*., 2003). Due to over exploitation, this tree has become the first extensively traded timber species to be listed in Appendix II of the CITES in 2002 (Blundell, 2004). *S.macrophylla* and *S.mahogany* were introduced to South India in 1872, from Belize (Lemmens, 2005). *S.macrophylla* was introduced to Kerala in 1893.

One of the issues with exotics is the narrow genetic diversity due to the limited sources of seeds that often form the basis of the species' introduction. The available diversity is further reduced due to selective removal of better individuals (dysgenic selection) from the population (Navarro & Her-nandez 2004, Cornelius *et al*., 2005). Higher genetic variation is essential for survival, good growth and viability of the species in the long term. Variability also enhances resistance to acute and chronic stressors, such as pests and diseases, and the effects of global warming. Since Mahogony has been grown in diverse edaphic and climatic conditions over 125 years in Kerala, the scope for developing local landraces adapted to the varying stresses exists.

The present investigation was carried out to explore the diversity existing among *Swietenia macrophylla* in Kerala and trace the development of any local land races in Kerala. The study also attempted to select candidate plus trees for further tree breeding in the species.

MATERIALS AND METHODS

The *S. macrophylla* trees were enumerated from fifteen locations from the state of Kerala. The fifteen randomly selected locations spread over three different agro-ecological zones based on altitude, rainfall, soil and topography of the state were selected for the study. Seven locations (Koorachundu, Vadakara, Taliparamba, Puduppady, Chakkittapara, Kottayam, Elathur) belonged to Northern Midlands (20 -100 m altitude), Thee locations (Nileshwar, Padne, Trikarippur) belonged to the plains (< 30 m altitude) of Malapuram type, and five locations (Kalpetta, Sulthan Bathery, Mananthavady, Eramanellur, Padinjarethara) belonged to high ranges (> 100 m altitude) in the agro climatic classification (KAU, 2011). Candidate trees of *S. macrophylla* trees were located and enumerated from farmers' fields and all individual trees were geo-tagged.

Morphological observations of quantitative and qualitative parameters were recorded in the field. Clean bole height (CBH and the crown length were measured using Vertex IV hypsometer. The tree girth at breast height (GBH) was estimated using a measuring tape. The crown diameter was estimated as the average of the diameters at the widest axis and an axis perpendicular to it. Pilodyn penetration depth was used as an estimate of relative wood density. Wood Qualitative characters like verticality of the stem, bole swellings, branch angle, apical dominance, forking, self-pruning ability, foliar and stem damage were recorded. The variations in the qualitative traits were determined using the scoring method developed by Jayaraj (1997). A total of 593 candidate trees were located over the sampling area and enumerated for assessing the variability.

A multi stage selection process was employed for the selection of plus trees from the candidate trees. In the initial stage, plus trees were selected using the baseline regression method (Rudolf, 1956). For this, the regression of trunk volume vs. crown volume of each candidate tree was determined. Trunk volume was calculated using the quarter girth formula and crown volume was calculated as the product of squared crown diameter and the crown length. Trees above the regression lines were selected. In the second stage, tree scoring was used to select from the trees selected in the first stage. Trees that have the highest scores for qualitative characteristics among the trees selected at the first were selected as plus trees.

The selected plus trees were subjected to hierarchical clustering analysis based on their qualitative and quantitative characters. Cluster analysis was conducted using Minitab software based on squared Euclidean distance.

RESULTS AND DISCUSSION

Based on a two stage sampling, 45 plus trees were selected and assigned accession numbers from FCV-SM-01 to FCV-SM-45 (**Table 2**). The regression analysis of *Swietenia macrophylla* from fifteen locations had shown a strong relationship between crown volume and trunk volume (R^2 = 0.58 to 0.78). The average clean

Table 1. Details of the morphological parameters of *Swietenia macrophylla* in Kerala

S.No.	Locations	Number of candidate trees	GBH (m)		Clean bole height (m)		Crown width (m)		Crown length (m)	
			max.	min.	max.	min.	max.	min.	max.	min.
1	Kalpetta	50	1.85	0.7	10	3	15	6.2	22	8.9
2	Sulthan Batherry	50	1.9	0.65	12.9	2.9	15	5.5	18	5
3	Padinjarethara	35	1.5	0.75	10	3.9	13.2	7	21	8
4	Eramanellur	35	1.7	0.65	12.1	3	12	5.5	18	6
5	Mananthavady	37	1.6	0.75	15	4.3	1.4	6	28	6
6	Puduppady	50	1.85	0.8	13	2.5	11.5	4.5	27	6
7	Chakkittapara	50	1.7	0.79	15	3.7	15	4	20	6
8	Kottayam	36	1.89	0.76	11.6	3.5	11.5	4.5	13	4.3
9	Taliparamba	37	1.8	0.79	16	3	19.4	5	22	9
10	Koorachundu	34	1.35	0.6	12	3	13	6	16	4.8
11	Elathur	35	1.65	0.75	10	4	13	5	23	9
12	Vadakara	40	1.85	0.75	12.5	2.9	10	4.5	28	6
13	Trikarippur	34	1.54	0.71	15	6	13.4	5	9	4
14	Neeleswaram	35	1.5	0.78	13.4	5	15	4.9	11	6.5
15	Padne	35	1.4	0.76	12.1	5	12	6	12	4
	Total	593								
	Mean		1.19		8.21		9.42		12.7	
	SD		0.49		4.81		4.49		7.9	

Table 2. Morphological characters of forty-five CPTs of *Swietenia macrophylla* from different locations

Altitude	Locality	Tree ID Number	Accession Number	Location	Clean bole height (m)	GBH (m)	Crown width (m)	Crown length (m)	PIN* (mm)	Total score
High land (above 100 m)	Kalpetta	K-01	FCV-SM-01	11°36'43"N 76°04'14"E	9.50	1.55	9.50	13.00	21.00	39
		K-14	FCV-SM-02	11°36'45"N 76°05'18"E	10.40	1.30	9.00	14.00	23.00	39
		K-15	FCV-SM-03	11°36'30"N 76°04'22"E	9.20	1.40	10.50	16.00	22.00	37
	Sulthan bathery	SB-20	FCV-SM-04	11°41'25"N 76°15'23"E	11.40	2.00	9.00	10.00	22.50	42
		SB-31	FCV-SM-05	11°41'22"N 76°15'24"E	7.50	1.70	9.50	13.00	21.00	37
		SB-37	FCV-SM-06	11°41'21"N 76°15'23"E	6.50	1.55	8.00	12.00	21.00	39
	Padinjarethara	P-11	FCV-SM-07	11°40'12"N 75°58'29"E	11.60	0.95	12.00	12.50	22.50	37
		P-18	FCV-SM-08	11°40'28"N 75°58'26"E	10.60	0.95	11.30	12.00	21.50	39
		P-24	FCV-SM-09	11°40'31"N 75°58'22"E	11.00	1.15	12.00	15.00	23.00	37
	Eramanellur	KA-13	FCV-SM-10	11°41'52"N 76°06'17"E	11.80	1.35	15.00	15.50	22.00	39
		KA-20	FCV-SM-11	11°41'57"N 76°06'18"E	9.50	0.94	12.90	13.00	22.00	39
		KA-25	FCV-SM-12	11°42'01"N 76°06'16"E	13.20	1.10	13.00	12.00	21.00	42
	Mananthavady	M-11	FCV-SM-13	11°48'33"N 75°56'57"E	11.00	1.25	10.00	9.50	21.00	37
		M-18	FCV-SM-14	11°48'43"N 75°56'58"E	10.00	1.32	11.00	11.10	22.50	40
		M-35	FCV-SM-15	11°48'45"N 75°56'45"E	12.00	1.30	11.50	8.30	21.00	39
Mid land (20 – 100 m)	Ppuduppady	PU-15	FCV-SM-16	11°27'11"N 75°59'48"E	6.00	1.85	11.00	10.50	22.50	40
		PU-20	FCV-SM-17	11°27'18"N 75°59'46"E	10.40	1.65	12.00	12.40	21.50	36
		PU-35	FCV-SM-18	11°27'54"N 75°59'27"E	6.00	1.70	13.00	15.30	21.50	37
	Chakkittapara	CH-12	FCV-SM-19	11°36'07"N 75°49'24"E	12.30	1.20	12.00	8.70	22.00	40
		CH-25	FCV-SM-20	11°36'09"N 75°49'30"E	11.50	1.10	8.00	11.10	22.00	40
		CH-30	FCV-SM-21	11°36'08"N 75°49'23"E	12.50	1.30	9.00	10.40	21.00	41
	Kottayam	KO-21	FCV-SM-22	11°49'13"N 75°32'59"E	12.00	0.75	8.90	9.00	21.00	42
		KO-26	FCV-SM-23	11°49'08"N 75°32'59"E	11.50	1.30	10.00	9.00	22.00	39
		KO-29	FCV-SM-24	11°49'03"N 75°32'55"E	13.00	1.24	10.00	11.80	21.00	41
	Taliparamba	TA-11	FCV-SM-25	12°10'09"N 75°23'18"E	11.50	1.30	8.70	11.00	22.00	36
		TA-16	FCV-SM-26	12°10'10"N 75°23'20"E	13.40	1.35	9.50	10.00	21.00	37
		TA-20	FCV-SM-27	12°10'25"N 75°23'30"E	11.00	1.45	12.00	12.00	21.00	41
	Koorachundu	KH-21	FCV-SM-28	11°30'47"N 75°53'18"E	11.00	1.20	10.50	7.00	22.00	40
		KH-28	FCV-SM-29	11°30'41"N 75°53'19"E	10.00	1.00	11.20	12.00	21.00	39
		KH-30	FCV-SM-30	11°30'26"N 75°53'34"E	11.10	0.85	9.00	9.00	21.00	41
Low land (Below 20 m)	Elathur	EL-5	FCV-SM-31	11°20'25"N 75°44'20"E	10.00	0.95	10.50	12.00	22.00	37
		EL-15	FCV-SM-32	11°20'02"N 75°44'17"E	10.00	1.10	9.00	11.50	23.00	37
		EL-30	FCV-SM-33	11°20'06"N 75°44'12"E	9.00	1.40	9.50	14.00	23.00	40
	Vadakara	V-12	FCV-SM-34	11°35'31"N 75°35'20"E	8.00	1.45	9.00	11.00	22.00	42
		V-15	FCV-SM 35	11°35'27"N 75°35'22"E	11.5	1.35	11.5	12.4	21.00	41
		V-17	FCV-SM-36	11°35'26"N 75°35'27"E	10.00	1.15	9.00	9.50	23.00	42
	Trikarippur	TR-8	FCV-SM-37	12°08'48"N 75°10'42"E	9.70	1.30	10.00	9.00	21.00	40
		TR-13	FCV-SM-38	12°08'45"N 75°10'37"E	10	1.5	9.5	9	21	42
		TR-23	FCV-SM-39	12°08'45"N 75°10'46"E	8.5	1.3	11.5	10	22	42
	Neeleswaram	N-12	FCV-SM-40	12°15'23"N 75°07'41"E	10.5	1.5	8	9	21	37
		N-16	FCV-SM-41	12°15'28"N 75°07'41"E	10.3	1.35	11	8.9	21	40
		N-21	FCV-SM-42	12°15'37"N 75°07'40"E	12.1	1.45	8	10	21.5	42
	Padne	PD-11	FCV-SM-43	12°15'10"N 75°06'52"E	12	1.05	10.5	11	21.5	40
		PD-18	FCV-SM-44	12°15'06"N 75°06'49"E	12.5	0.9	11.6	9.5	22	37
		PD-25	FCV-SM-45	12°14'58"N 75°06'49"E	9.8	0.98	10.5	8.5	21	40
			Mean		10.49	1.33	10.43	10.89	21.6	
			CV		11.9	17.29	15.23	3.5	3.25	
			SD		1.25	0.23	1.6	0.386	0.704	

*Pin penetration depth

bole height measured for forty-five plus trees was 10.49 m. The CBH ranged from 13.4 m (FCV-SM-26) to 6 m (FCV-SM-18 and FCV-SM-16). A total number of twenty-two trees had clear bole height above the mean value. The average girth at breast height measured was1.33 m. The GBH ranged from 2.00 m (FCV-SM-04) to 0.75 m (FCV-SM-22). Eighteen CPTs recorded the value above the mean GBH. The standard deviation from the mean and coefficient of variation were 0.23 and 17.29 per cent, respectively. The average crown width for forty-five CPTs was 10.43 m. The maximum value for crown width observed was 15 m (FCV-SM-10) and the minimum value measured was 8 m (FCV-SM-6 and FCV-SM-20). A total number of twenty-three CPTs recorded the measurements above the average value. The standard deviation from the mean was 1.6 and the coefficient of variation was 15.23 per cent. The average value of the crown length measured for the CPTs was 10.89 m. The maximum value was 16 m (FCV-SM-03) and the minimum value was 7 m (FCV-SM-28). A total number of twenty-five CPTs recorded the crown length value above the mean. Pilodyn pin penetration depth of forty-five plus trees did not show much variation (CV of 3.25). The average pin penetration depth was 21.6 mm. The maximum pin penetration depth was measured at 23 mm (FCV-SM-02 and FCV-SM-09). The minimum value was 21 mm was observed for 19 CPTs (FCV-SM-01, FCV-SM-05, FCV-SM-06, FCV-SM-12, FCV-SM-13, FCV-SM-15, FCV-SM-21, FCV-SM-22, FCV-SM-24, FCV-SM-26, FCV-SM-27, FCV-SM-29, FCV-SM-30, FCV-SM-35, FCV-SM-37, FCV-SM-38, FCV-SM-40, FCV-SM-41 and FCV-SM-45). A total number of twenty-one trees had a pin penetration depth above the average value. The correlation between all the quantitative characters is shown in **Table 3**. A significant negative correlation was observed between CBH and GBH at 0.01 levels. The clean bole height had no significant correlation with any other characters.

Several scientists had worked in plus tree selection of hardwood using the base line method and found it effective. Plus trees of *Melia dubia* from different parts of Kerala have been selected using a base line method (Binu, 2019). Candidate plus trees of *M. azaderach* have been selected from different agro -climatic areas of Punjab by Dhillon *et al*. (2009).

The scores of the qualitative characters of the plus trees ranged from 42 for CPTs FCV-SM-04, FCV-SM-12, FCV-SM-22, FCV-SM-42 and FCV-SM-39. The minimum score of 36 was obtained for CPTs FCV- SM-17, FCV-SM-24 and FCV-SM- 25 indicating much lower variation in qualitative characters of trees and these are mostly genetically determined. However, successful selections based on qualitative traits have been made in *Ailanthus excelsa* (Daneva *et al*., 2018), *Azadirachta indica* (Dhillon *et al*., 2003), *Dalbergia sissoo* (Bangarwa, 1993; Yadav *et al*., 2005) and *Salix alba* (Paray *et al.*, 2017).

Hierarchical cluster analysis classified the forty-five plus trees into five clusters (**Table 4 & Fig. 1**). Cluster II had the maximum number of trees with 35 accessions and cluster III and cluster IV had only one accession each.

Table 3. Correlation of quantitative characters of CPTs of *Swietenia macrophylla*

Parameters	Clean bole height	GBH	Crown width	Crown length	Pin penetration depth
Clean bole height	1				
GBH	-0.444**	1			
Crown width	0.045	0.112	1		
Crown length	0.286	0.167	0.259	1	
Pin penetration depth	0.147	0.001	0.38	0.284	1

Table 4. Clusters of *Swietenia macrophylla* CPTs based on their morphological characters

Cluster	Accessions
Cluster I	FCV SM-01, FCV- SM-06, FCV-SM-03, FCV-SM-05, FCV-SM-18,FCV-SM-16
Cluster II	FCV-SM-02, FCV-SM-33, FCV-SM-33, FCV-SM-33, FCV-SM-33, FCV-SM-36 FCV-SM-08, FCV-SM-08, FCV-SM-08, FCV-SM-08, FCV-SM-12, FCV-SM-12 FCV-SM-35, FCV-SM-35, FCV-SM-35, FCV-SM-28, FCV-SM-38, FCV-SM-20 FCV-SM-21, FCV-SM-42, FCV-SM-42, FCV-SM-30, FCV-SM-45, FCV-SM-43 FCV-SM-04, FCV-SM-17, FCV-SM-24, FCV-SM-25, FCV-SM-25, FCV-SM-07 FCV-SM-31, FCV-SM-13, FCV-SM-26, FCV-AM-44
Cluster III	FCV-SM-09
Cluster IV	FCV-SM-10, FCV-SM-19
Cluster V	FCV-SM-40

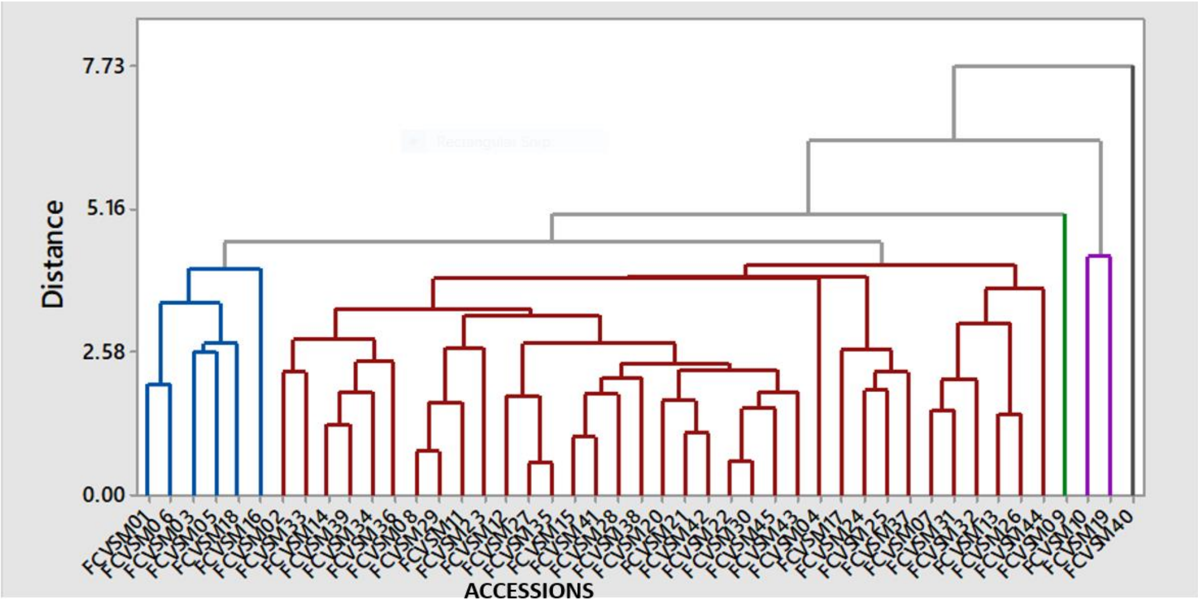

Fig. 1. Dendrogram on morphological characters of forty- five CPTs of *Swietenia macrophylla*

Single accession cluster can be either inferior or superior in nature. The average values of CBH, GBH, crown width, crown length, the pin penetration depth of accession in all five clusters were 10.39 m, 1.35 m, 10.80 m, 13.56 m, 21.83 mm, respectively (**Table 5**).

Trees from different regions grouped in one cluster, indicating that the variation in geographic regions was not consistent with the genetic diversity indicating a lack of landraces. Kaushik *et al*. (2011) has also observed the same pattern in *Pongamia pinnata*. Cluster II had the maximum intra cluster distance (2.45), followed by cluster I (2.21) and cluster IV (2.15) (**Table 6**). The results indicate that the cluster with the maximum intra cluster distance had greater genetic distance within the cluster, which can be attributed either to genetic or environmental factors. The highest inter cluster distance was observed between cluster IV and cluster V (9.33) and the lowest between cluster I and cluster II (3.19). According to Ghader *et al.* (1984), higher inter cluster distance indicates a greater number of contrasting alleles at the desired loci and these loci recombines in the F_2 and F_3 generation following a

Table 5. Mean value of quantitative characters among the clusters of CPTs of *Swietenia macrophylla*.

Variables	Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V	Mean	SD	CV (%)
Clean bole height (m)	7.45	10.95	11	12.05	10.5	10.39	1.73	16.7
GBH (m)	1.625	1.22	1.15	1.27	1.5	1.35	0.199	14.7
Crown width (m)	10.25	10.28	12	13.5	8	10.80	2.07	19.1
Crown length (m)	21	10.71	15	12.1	9	13.56	4.7	34.6
Pin penetration depth (mm)	21.5	21.69	23	22	21	21.83	0.74	3.4

Table 6. Matrix showing inter and intra cluster distance

	Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V
Cluster I	2.21				
Cluster II	3.19	2.45			
Cluster III	5.06	4.37	0.00		
Cluster IV	6.28	5.37	6.57	2.15	
Cluster V	7.7	7.11	9.12	9.33	0.00

cross of distantly related parents and there will be great opportunities for the effective selection for yield factors.

Based on cluster mean, accessions from cluster IV are important for clean bole height and crown width and accessions from cluster I are important for GBH and crown length, accessions from cluster V are important for pin penetration depth. Crossing parents belonging to more divergent clusters would result in maximum heterosis and wide variability in genetic structure (Singh and Chaudary, 1985). In the present study, cluster II is more divergent than others. The selection of parents for breeding should also account for the special advantage of each cluster and each genotype within a cluster based on the objectives of hybridization (Chahal and Gosal, 2002). Studies conducted in *Pinus gerardiana* (Kant *et al.*, 2006), *Melai dubia* (Binu, 2019) and *Ailanthus triphysa* (Lalnunpuia *et al.,* 2021) also had shown similar trends. Therefore, genetic diversity should be given due consideration while selecting plus trees.

In the present study, high variation was observed in many qualitative and quantitative characters. This is very important in exotic species like *S. macrophylla*. However, the CPTs when clustered did not exhibit any geographical pattern indicating the lack of development of any land races in the species. The variation that exists in the *S. macrophylla* trees in Kerala can be exploited for further tree improvement programmes. Hybridization of trees from the different clusters that show better performance with specific characters may also be ideal for improving the desired characters.

ACKNOWLEDGEMENT

The authors acknowledge the Kerala Agricultural University for providing financial support and facilities for the conduct of the study.

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