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Research Article

Provenances variation in growth traits of A*quilaria malaccansis* Lam. suitable to south indian condition

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Abstract
Aquilaria malaccensis Lam. is one of the important species to produce resin-impregnated heartwood that is fragrant and highly valuable and traded internationally. A field experiment was laid out in RBD by using plants raised from 22 provenances collection of *Aquilaria malacanssis* from 3 states of North-Eastern hill regions of India. The genotypes viz., MDLY, NHJA and KHOW-1 recorded significantly higher values than the rest of the genotypes. Genotypic coefficients of variability were less than phenotypic coefficient of variability. Maximum variability was observed for volume index (18.98) followed by number of branches (16.78). Collar diameter (2.465) was recorded as minimum GCV value. Volume index (21.35) was registered maximum PCV followed by number of branches (17.85). High heritability was observed for plant height (0.966) followed by number of branches (0.883) and volume index (0.790). Minimum genetic advance was estimated for collar diameter (2.284%) and maximum for volume index (34.75%). Plant height was significant and positively correlated with volume and collar diameter at phenotypic and genotypic level. Collar diameter showed positive and highly significant correlation with volume index. The path analysis indicated that plant height and collar diameter has maximum direct effect on volume index. This study reveals that selection of better plants with higher variability and other juvenile growth traits of *Aquilaria malaccansis* provenances is suitable to grow in South Indian condition. And also these characters shoud be used as selection criterion for further improvement of yield in *Aquilaria malaccansis.*

Keywords:
Aquilaria malaccensis, Genetic variability, Correlation, Path analysis.

Introduction

Aquilaria malaccensis Lam. is the best known species of agarwood(Gaharu). It is one of the 15 tree species in the Indomalesian genus Aquilaria of family*Thymelaeaceaeand* 8 are known to produce resin-impregnated heartwood (Ng *et al.,* 1997). There are many names for this resinous wood, including agar, agarwood, aloe(s) wood, eaglewood, gaharu and kalamabak. This wood is in high demand for medicine, incense and perfume across Asia and the Middle East. The tree grows in natural forests at an altitude of a few meters above sea level to about 1000 meters, and it grows best around 500 meters in locations with average daily temperatures of 20 to 22ºC (Wiriadinata, 1995). It is a large evergreen tree, growing over 15-40 m tall and 0.6-2.5 m in diameter, and has white flowers (Chakrabarty*et al*., 1994; Sumadiwangsa, 1997). The 2002 IUCN Red List classifies this species as Vulnerable. Two species of *Aquilaria* are found in India: *A. khasiana* and *A. malaccensis,* although a third, *A. macrophylla* Miq. is found in the Nicobar Islands. Agarwood has been used for medicinal purposes for thousands of years, and continues to be used in ayurvedic, Tibetan and traditional East Asian medicine (Chakrabarty *et al*., 1994). Agarwood is extremely valued by luxury perfume, fragrance and soap manufacturers. Both agarwood smoke and oil are customarily used as perfume in the Middle East (Chakrabarty *et al*., 1994).

The quantitative characterization for improvement has been and remains the essential basis for phenotypic selection in any breeding programme. However, the real tree improvement depends upon the knowledge of genetic variability and its components. The extent of variability is measured by GCV and PCV which provides information about relative amount of variation in different characters (Mousmi syed *et al.*, 2013). Heritability of a character is important for the tree breeder because it provides him an idea of the extent of genetic control for the expression of a particular character (Chopra, 2000). However, Johnson *et al.* (1955) stated that heritability estimates together with genetic advance are more important than heritability alone to predict the resulting effect of selecting the best individuals. Most studies on genetic parameters in different tree species were focused on Jatropha (Parthiban *et al.*, 2011), *Azardiracta indica* (Mousmi syed *et al.*, 2013), *Simarouba glauca* (Kumaran *et al.*, 2010), *Madhuca indica* (Mohamed Saleem and Afaq majid, 2013) and *Leuceana leucocephala* (Chavan Sangram and Keerthika, 2013).

The ultimate goal of *Aquilaria malaccensis* breeding is to improve the species oil quantity and quality. This could be achieved through selection of superior genotypes which is always pursued. Stem diameter is an important trait considered for oil exploitation and it is associated with a number of component characters, which in turn are interrelated. As more traits are included in the correlation studies, the inherent association become complex. For this reason, paths analysis becomes necessary. This is because it measures the direct and indirect influence of one variable upon another and permits the separation of relative contribution of different traits to the traits of measured interest (Dewey and Lu, 1959). Correlation and path coefficient analysis together gives a clear picture of interrelationships and relative contribution of independent characters on dependent variable which enables to plant breeder to apply suitable selection procedures for crop improvement.

Study of morphometric traits in field trials was earlier the dominating technique and it is still today the most robust and valid way of assessing genetic variation. However, variation studies using morphometric traits in *Aquilaria malaccansis* is not attempted and thus needs research. The objective of the present investigation was to quantify the magnitude of genetic variability present in the existing base population study the association among characters and to identify important yield attributing characters, selection for which would help in development of high yielding *Aquilaria malaccansis* genotypes.

Material and Methods

The survey has been conducted in predominant *Aquilaria malaccansis* growing areas of India and 22 different provenances from North-Eastern states of Assam(6), Tripura (10) and Nagaland(6) were selected by subjective grading method in natural forest and comparison tree selection method in plantation. Based on morphological characters such as diameter, height, number of branches and clear bole height of superior Agar wood genetic resources were selected. The experiment was conducted at Forest College and Research Institute, Tamil Nadu Agricultural University, Mettupalayam situated at 11^o 19’N longitude and 76 ^{o}56’E latitude at 300MSL during the year 2013-2014. The experimental site receives an annual rainfall of 800mm/annum with the maximum and minimum temperature of 33.8^{o}C and 21.2 ^{o} C respectively. The soil is predominantly red lateritic with a pH of 7.1. A progeny evaluation trial has been laid out at Forest College and Research Institute, Mettupalayam during 2013. Progenies of 22 different genotypes were planted in a Randomized Block Design (RBD) with three replications. The size and spacing were 2 x 2m with 9 seedlings per replication. Data was collected from 5 seedlings taken at random on plant height (cm), collar diameter (cm), number of branches and volume index. Correlation coefficients between different pairs of trait were determined at genotypic and phenotypic levels.

The data recorded at 240 DAP were subjected to statistical analysis. Biometric data for plant height, collar diameter and number of branches were subjected to analysis of variance (Panse and Sukhatme, 1978). Estimation of genetic parameters *viz*., variability, PCV and GCV were computed (Burton, 1952). Heritability and genetic advance were computed (Lush, 1940; Johnson *et al*., 1955). Phenotypic and genotypic correlation coefficients were calculated according to the method suggested by Goulden (1952). Path coefficient analysis was estimated as suggested by Dewey and Lu (1959) to apportion the genotypic correlation coefficients in to direct and indirect effects.

Result and Discussion

<u>Growth performance of provenances</u>**:** Significant differences were observed on morphological growth traits (240 days after planting) among the evaluated provenances of *A. malaccensis* viz., plant height, collar diameter, number of branches and volume index at four growth periods. Five provenances *viz.*, MDLY (70.33 cm), UDLY-1 (60.22 cm), NHJA (72.13 cm), KHOW-1 (65.43 cm) and KHOW-2 (59.33 cm) registered significantly higher values for plant height compared to general mean (58.08 cm). The collar diameter ranged from 1.400 (NHJA and KHOW-1) to 1.206 (KUMA). Two provenances *viz.*, NHJA (1.400 cm) and KHOW-1 (1.400 cm) recorded significantly higher collar diameter values compared to general mean (1.294). Number of branches varied from 11.66 (NHJA) to 6.333 (AMBS). The volume index ranged from 141.7 (NHJA) to 69.80 (CHEK-3) and four progenies viz., MDLY (125.4), UDLY-1 (115.9), NHJA (141.7) and KHOW-1 (124.0) recorded significantly higher value compared to

general mean (90.75). Among the twenty two provenances, three genotypes viz., MDLY, NHJA and KHOW-1 proved to be a good performer which expressed superiority for four characters viz., plant height, collar diameter, number of branches and volume index investigated (Table.3). The progenies and provenances in various tree species like *Santalum album* (Bagchi and Sindhu Veerendra, 1991), *Dalbergia sissoo* (Rawat and Nautiyal, 2007) and *Melia dubia* (Kumar *et al*., 2013) which thus lend support to the current findings in *Aquilaria malaccansis* genetic resources. Similar results of superiority of provenances in *Azardiracta indica* (Jain and Dhar, 2008) and in *Acacia catechu* (Gera and Gera, 2006) were also lend support to the current investigation.

Genetic variability studies**:** Genetic variability in tree species is a gift to mankind, as it forms the basis for selection and further improvement of species. The results clearly indicated that for a majority of traits there is much scope for selection for improvement in *Aquilariamalaccansis*. Variations among progenies are commonly used as an estimate of total genetic variation and to calculate the degree of genetic control for a particular trait. (Himanshu meena *et al.*, 2013). Character with high GCV have more improvement potential than those with moderate, and those with moderate are superior to those that were low (Olayiwola and Soremi, 2014). Estimates of PCV were higher than GCV for all traits. In the current study, volume index (21.35) was registered maximum phenotypic coefficient of variability followed by number of branches (17.85).Plant height (14.16) was expressed moderate PCV and collar diameter (5.480) had lowest PCV value. Genotypic coefficient variability ranged from 0.857 to 23.05. Maximum variability was observed for volume index (18.98) followed by number of branches (16.78). Collar diameter (2.465) was recorded as minimum GCV value (Table.5). The value of GCV is also high for volume index and number of branches. The higher PCV than corresponding GCV for all traits implies that the variability observed were not solely under genotypic influence but with some levels of environmental influence justifying the need to explore more genetic parameters to ascertain the traits to be considered. The variability parameter estimates in the study are in close approximation with the findings of genetic parameters in *Azadirachta indica* (Dhillon, *et al*., 2003), *Acacia nilotica* (Ginwal and Mandal, 2004), *Melia dubia* (Kumar *et al*., 2013) and also in progenies of *Dalbergia sissoo* (Dogra *et al*., 2005) which lend support to the findings of current investigation.

Heritability and Genetic Advance**:** The heritability states the magnitude of inheritance of quantitative traits while genetic advance provide needful information for formulating suitable selection procedure (Sumathi *et al.,* 2010). The heritability estimates help the breeders in selection based on the phenotypic performance. In the present study, heritability was high for plant height (0.966), number of branches (0.883) and volume index (0.790) indicating that the variability for these traits are under genetic control and therefore heritable. Low heritability for collar diameter (0.202) indicating moderate genetic control and implies that direct selection for these traits may not be very successful (Table.4). Hence, the high heritability recorded in plant height, number of branches and volume index, so it could be a reliable indicator for further improvement programme. Similarly higher and lower heritability values for different growth attributes were earlier reported in Eucalyptus (Dogra and Luna, 2006) and in Casuarina (Rao *et al*., 2001) which lend support to the current findings.

The simultaneous consideration of estimates of heritability and genetic advance in predicting the values of selection is more valuable than heritability used singly. Character with high genetic advance would response favorably to selection as it implies preponderance of additive gene effect. The estimate of genetic advance in percentage mean varied from 34.75% to 2.284%. Minimum genetic advance was estimated for collar diameter (2.284%) and maximum for volume index (34.75%) followed by number of branches (32.51%) and plant height (28.20) (Table.4). In this study, plant height and volume index combined high heritability and high genetic advance which indicates high additive genetic variance for the trait. Plant height and volume index could therefore be considered as important in *Aquilaria malaccansis* improvement programme. The characters with high heritability coupled with higher genetic gain could act as a reliable indicators as evidenced in *Prosopis cineraria* and also in poplars (Tewari, 1994; Singh *et al.,* 2001).

Correlation studies**:** Correlation analysis suggested that the magnitude of genotypic correlation were higher as compared to their corresponding phenotypic correlations indicating the inherent relationship among the characters studied (Prajapati *et al.,* 2014). Plant height was significant and positively correlated with volume index at phenotypic (0.885) and genotypic (1.000) levels and collar diameter at phenotypic (0.430) but not with genotypic level. Collar diameter showed positive and highly significant correlation with volume index at phenotypic (0.763) level. Number of branches showed positive and significant phenotypic (0.469) and genotypic (0.530) correlations with volume index. Volume index recorded positive and highly significant phenotypic (0.885) and genotypic (1.000) correlations with plant height. (Table 5&6). This result is in agreement with the findings of *Leuceana leucocephala* (Chavan Sangram and Keerthika, 2013) and *Pongammia pinnata* (Rao *et al*., 2011). In the current study the genotypic correlation coefficients were higher than the phenotypic correlation coefficients for almost all the traits thus indicating the less environmental effect and true representation of the genotype by the phenotype as evidenced in Poplars (Lone and Tewari, 2008).

In *Aquilaria malaccansis*, one of the important traits considered for oleo resin exploitation is stem diameter and traits positively and significantly associated with collar diameter such as plant height and volume index are therefore of interest to the breeder, since selection of one or more of these traits is likely to improve the oleo resin yield. This finding clearly indicates that plant height, collar diameter and volume index could act as reliable indicators for selection and there is a scope for simultaneous improvement of these traits through recurrent selection.

Path coefficient analysis: Path analysis gives information on direct and indirect effects of component traits on yield and hence helps in selection for genetic improvement (Das *et al.*, 2010). Correlation study measures mutual association without regard to causation while path coefficient analysis indicates the causes and measures their relative importance on the causal factors (Dewey and Lu, 1959). Among the traits studied, plant height, collar diameter and number of branches exercised positive direct effect on volume index. The highest positive direct effect on volume index was exerted by plant height (0.654) followed by collar diameter (0.302), number of branches (0.077). Plant height expressed its positive indirect effect via collar diameter (0.315) followed by number of branches (0.033) on volume index. Collar diameter registered positive indirect effect on volume index through plant height (0.684) followed by number of branches (0.042).This trait exerted a positive indirect effect on volume index via plant height (0.286) and collar diameter (0.077) (Table.7).

Association of characters ascertained through such correlation and path coefficient studies had also been found to form the criteria for selection in *Casuarina equisetifolia* (Ashok Kumar and Gurumurthi, 1998), Jatropha (Parthiban *et al.*, 2011), *Leuceana luecocephala* (Chavan Sangram and Keerthika, 2013) and *Madhuca indica* (Mohamed saleem Wani and Afaq Majid Wani, 2013). The present investigation envisaged that high and positive association coupled with intensive direct effect of plant height followed by collar diameter and number of branches could be used as selection criteria in *Aquilaria malaccensis* tree improvement programme.

A total twenty two candidate plus trees have been selected in three states of North-eastern hill region of India by subjective grading and comparison tree selection method. Result of the present study revealed that the three progenies viz., MDLY, NHJA and KHOW-1 proved superior in terms of important biometric attributes which is suitable to grow in South Indian condition. Considering this experiment into account three progenies viz., MDLY, NHJA and KHOW-1are brought under sharp focus for immediate utilization and deployment for future improvement programme. The variability study indicated that volume index registered highest phenotypic and genotypic coefficients of variances. The genetic advance as per cent of mean of volume index was highest among all traits. This finding clearly indicates that plant height, collar diameter and volume index could act as reliable indicators for selection and there is a scope for simultaneous improvement of these traits. The high and positive association coupled with intensive direct effect of plant height followed by collar diameter and number of branches could be used as selection criteria in *Aquilaria malaccensis* tree improvement programme.

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Table.1. Details of Location, Latitude, Longitude, Elevation (m) of superior genetic resources of Agar wood provenance

Provenances	Location	State	Latitude	Longitude	Elevation (m)
MDLY	Modhertally	**Assam**	$26^0$08.100	$92^0$49.771	123
UDLI-1	Udali-1	**Assam**	$25^0$53.304	$93^0$00.604	89
UDLI-2	Udali-2	**Assam**	$25^0$53.303	$93^0$00.600	90
NHJA	Nahaurani-Jangoan village	**Assam**	$26^0$38.856	$94^0$03.318	80
NHSU	Nahaurani- Sumoni	**Assam**	$26^0$38844	$94^0$03.348	78
HAKH	Hatiekhowa village	**Assam**	$26^0$36.476	$94^0$01.826	82
KHOW-1	Khowai-1	**Tripura**	$24^0$04.186	$91^0$36.868	40
KHOW-2	Khowai-2	**Tripura**	$24^0$06.170	$91^0$36.840	47
AMBS	Ambassa	**Tripura**	$23^0$55.138	$91^0$50.522	74
CENT-1	Central nursery-1	**Tripura**	$23^0$54.891	$91^0$53.144	115
CENT-2	Central nursery-2	**Tripura**	$23^0$54.927	$91^0$53.175	126
KUMA-R	Kumargath-RFO house	**Tripura**	$24^0$10.501	$92^0$01.922	38
KUMA	Kumargath	**Tripura**	$22^0$09.695	$92^0$02.661	39
FUKO	Fukirkohi	**Tripura**	$24^0$10.700	$92^0$01.288	32
KUMA-RO	Kumargath-range office	**Tripura**	$24^0$10717	$92^0$01.923	61
ROWA	Rowa	**Tripura**	$24^0$22.084	$98^0$49.328	97
DI-FC	Dimapur-Forest colony	**Nagaland**	$25^0$54.733	$93^0$42.825	152
DI-TY	Dimapur- Tykho village	**Nagaland**	$25^0$53.189	$93^0$43.271	158
DIPU	Diphupur	**Nagaland**	$25^0$51.294	$93^0$45.493	160
CHEK-1	Chekieye village-1	**Nagaland**	$25^0$51.856	$93^0$45.049	162
CHEK-2	Chekiye village-2	**Nagaland**	$25^0$51.863	$93^0$45.479	164
CHEK-3	Chekiye village-2	**Nagaland**	$25^0$51.871	$93^0$45.488	165

Table.2. Morphological characters of superior genetic resources of Agar wood

Provenance Name	Location	GBH (cm)	Height (m)	Clear bole Height (m)	No.of Branches
MDLY	Modhertally	52.20	7.50	4.50	16
UDLI-1	Udali-1	68.00	16.5	4.00	20
UDLI-2	Udali-2	70.00	14.0	5.00	20
NHJA	Nahaurani-Jangoan village	89.00	19.5	9.00	21
NHSU	Nahaurani- Sumoni	81.00	19.0	5.00	17
HAKH	Hatiekhowa village	79.00	17.5	6.50	18
KHOW-1	Khowai-1	103.0	18.5	7.00	22
KHOW-2	Khowai-2	100.0	19.0	7.50	20
AMBS	Ambassa	390.0	27.0	7.00	52
CENT-1	Central nursery-1	110.0	18.0	12.0	10
CENT-2	Central nursery-2	127.0	22.0	11.0	17
KUMA-R	Kumargath-RFO house	147.0	25.0	10.0	18
KUMA	Kumargath	88.00	18.0	7.00	22
FUKO	Fukirkohi	87.00	16.0	2.00	18
KUMA-RO	Kumargath-range office	230.0	28.0	3.80	96
ROWA	Rowa	81.00	13.0	3.00	15
DI-FC	Dimapur-Forest colony	72.00	16.5	4.00	16
DI-TY	Dimapur- Tykho village	58.00	12.0	6.00	18
DIPU	Diphupur	72.00	17.5	7.50	16
CHEK-1	Chekiye village-1	87.00	18.0	6.50	24
CHEK-2	Chekiye village-2	75.00	17.0	7.00	17
CHEK-3	Chekiye village-2	83.00	16.5	7.00	18

Table.3. Variation in growth attributes for *Aquilariamalaccensis*genetic resources (240 DAP) in Field level

Sl.No	Name of the provenances	Plant height	Collar diameter	Number of Branches	Volume index
1	**MDLY**	70.33**	1.393	11.33**	125.4**
2	**UDLI-1**	60.22**	1.333	9.033	115.9**
3	**UDLI-2**	54.83	1.300	7.666	94.68
4	**NHJA**	72.13**	1.400*	11.66**	141.7**
5	**NHSU**	52.33	1.366	7.666	84.24
6	**HAKH**	54.70	1.300	7.666	87.90
7	**KHOW-1**	65.43**	1.400*	10.00**	124.0**
8	**KHOW-2**	59.33**	1.293	7.333	95.30
9	**AMBS**	49.46	1.300	6.333	83.59
10	**CENT-1**	55.44	1.246	7.000	86.01
11	**CENT-2**	52.32	1.280	9.333	85.72
12	**KUMA-R**	53.22	1.298	7.666	89.75
13	**KUMA**	50.22	1.206	7.000	71.48
14	**FUKO**	49.23	1.266	8.333	79.23
15	**KUMA-RO**	45.33	1.266	9.666*	72.65
16	**ROWA**	51.20	1.293	8.666	85.93
17	**DI-FC**	46.23	1.233	8.666	70.50
18	**DI-TY**	47.23	1.300	8.000	79.92
19	**DIPU**	48.43	1.286	8.000	80.34
20	**CHEK-1**	52.36	1.253	8.666	78.76
21	**CHEK-2**	55.33	1.300	9.333	93.45
22	**CHEK-3**	43.46	1.266	9.666*	69.80
	Mean	54.08	1.294	8.562	90.75
	SE.d	1.091	0.052	0.457	7.273
	CD (0.05)	2.203	0.106	0.924	14.68
	CD (0.01)	2.944	0.142	1.235	19.62

(** Significant at 1% level * Significant at 5% level)

Table.4. Genetic estimates of morphometric traits at 240 DAP

Traits	GCV	PCV	Heritability	Genetic Advance (%)
Plant height	13.92	14.16	0.966	28.20
Collar diameter	2.465	5.480	0.202	2.284
No. of branches	16.78	17.85	0.883	32.51
Volume index	18.98	21.35	0.790	34.75

Table. 5. Phenotypic and Genotypic correlation coefficient of morphometric attributes

Traits	Correlation coefficient	Plant height	Collar diameter	No. of branches	Volume index
Plant height	Phenotypic	1.000	0.430*	0.415*	0.885**
	Genotypic	1.000	1.043**	0.437*	1.000**
Collar diameter	Phenotypic		1.000	0.248	0.763**
	Genotypic		1.000	0.551**	1.028**
No. of branches	Phenotypic			1.000	0.469*
	Genotypic			1.000	0.530**
Volume index	Phenotypic				1.000
	Genotypic				1.000

(** Significant at 1% level * Significant at 5% level)

Table. 6. Path coefficient analysis of morphometric traits on Volume index

Traits	Plant height	Collar diameter	No. of branches	Correlation (r) with Volume index
Plant height	**0.654**	0.315	0.033	1.000**
Collar diameter	0.682	**0.302**	0.042	1.028**
No. of branches	0.286	0.166	**0.077**	**0.530****

Residual effect= 0.0992